MINDFUL UNIVERSE (March 1, 2006)

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PREAMBLE.

This book is about your nature as a human being. It is about the connection of your mind to your body.

You may think that that your mind---your stream of conscious thoughts, ideas, and feelings---influences your actions. You may believe that what you think affects what you do. You could be right. However, the scientific ideas that prevailed from the time of Isaac Newton to the beginning of the twentieth century asserted that your physical actions are completely determined by purely mechanical processes describable in purely mechanical terms. According to that earlier conception of nature, any belief that your conscious choices can make a difference in how you behave is an illusion. You were asserted to be, causally, a mechanical automaton.

We now know that that earlier form of science is fundamentally incorrect. During the first part of the twentieth century that mechanistic conception of nature was replaced by a new theory that reproduces all of the successful predictions of its predecessor, while giving also valid predictions about a host of phenomena that are strictly incompatible with our earlier idea of nature. No prediction of the new theory has been shown to be false.

The new theory differs from the old one in many interesting ways, but none is more significant than the causal role it gives to your conscious choices. These choices are not fixed by the new laws of physics, yet are asserted by those laws to have causal effects upon the physical world. This change abrogates the old notion of mechanical determinism. It permits your thoughts to influence your actions in a way that is not fixed by the physical laws, yet is in line with a growing body of empirical evidence. It allows an important kind of human freedom that nineteenth century physics forbids.

More than three quarters of a century have passed since this introduction of our conscious choices, unfettered by known laws, into the orthodox laws of physics. But the old notion of mechanical determinism still pervades our intellectual environment. The force of the prior idea continues to have a profound impact upon your life. It still drives the decisions of governments, schools, courts, and medical institutions, and even your own choices, to the extent that you are influenced by what you are told by pundits who expound as scientific truth a mechanical idea of the universe unsupported by orthodox contemporary physics.

The aim of this book is to explain to educated lay readers these twentieth century developments in science, and their relevance to our conception of ourselves. The main part of the book is complete within itself, but supplementary material that may interest some readers is appended

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1. Science and Human Values.

Science has improved our lives in many ways. It has lightened the load of tedious tasks and expanded our physical powers, thereby contributing to a great flowering of human creativity. On the other hand, it has given us also the capacity to ravage the environment on an unprecedented scale and to obliterate our species altogether. Yet along with this fatal power it has provided a further offering which, though subtle in character and still hardly felt in the minds of men, may ultimately be its most valuable contribution to human civilization, and the key to human survival.

Science is not only the enterprise of harnessing nature to serve the practical needs of humankind. It is also part of man's unending search for knowledge about the universe and his place within it. This quest is motivated not solely by idle curiosity. Each of us, when trying to establish values upon which to base conduct, is inevitably led to the question of one's place in the greater whole. The linkage of this philosophical inquiry to the practical question of personal values is no mere intellectual abstraction. Martyrs in every age are vivid reminders of the fact that no influence upon human conduct, even the instinct for bodily self preservation, is stronger than beliefs about one's relationship to the rest of the universe and the power that shapes it. Such beliefs form the foundation of a person's self image, and hence, ultimately, of personal values.

It is often claimed that science stands mute on questions of values: that science can help us to achieve what we value once our priorities are fixed, but can play no role in fixing these weightings. That claim is certainly incorrect. Science plays a key role in these matters. For what we value depends on what we believe, and what we believe is increasingly determined by science.

A striking example of this influence is the impact of science upon the system of values promulgated by the church during the Middle Ages. That structure rested on a credo about the nature of the universe, its creator, and man's connection to that creator. Science, by casting doubt upon that belief, undermined the system of values erected upon it. Moreover, it put forth a credo of its own. In that "scientific" vision we human beings were converted from sparks of divine creative power, endowed with free will, to automatons---to cogs in a giant machine that grinds inexorably along a preordained path in the grip of a blind mechanical process.

This mechanical picture of human beings corrodes not only the religious roots of moral values but in fact the entire notion of personal responsibility. Each of us is asserted to be a mechanical extension of what existed prior to one's birth. Over that earlier situation one has no control. Hence for what emerges, preordained, from that prior state one can bear no responsibility.

Given this conception of man the collapse of rational moral philosophy is inevitable. For this notion of the human being provides no rational basis for any value but self interest. Behaviour promoting the welfare of others, including future generations, becomes rational only to the extent that such behaviour serves one's own interests.

Hence science becomes doubly culpable. It not only undermines the foundations of earlier value systems, but also strips man of any vision of himself and his place in the universe that could be the rational basis for an elevated set of values.

This mechanical view of nature, and of man's place within it, dominated science until early into the twentieth century. According to that notion, the physical universe is composed of tiny bits of matter, and the unfolding of the observed world over the course of time is completely fixed by the interactions of these tiny localized realities with their immediate neighbors. Human beings, insofar as they are parts of this physically describable reality, are simply conglomerations of these tiny components whose motions are completely fixed by interactions at the atomic level.

During the twentieth century this simple picture of nature was found to be profoundly wrong. It failed not just in its fine details, but at its fundamental core. A vastly different conceptual framework was erected by the atomic physicists Werner Heisenberg, Niels Bohr, Wolfgang Pauli and their colleagues. Those scientists were forced to a wholesale revision of the entire subject matter of physical theory by the strange character of the new mathematical rules, which were invariably validated by reliable empirical data.

The earlier "classical" physics had emerged from the study of the observed motions of the planets and large terrestrial objects. The entire physical universe was then conceived to be made, essentially, out of miniaturized versions of these large visible objects. Rules were found that appeared to control the behaviour of these tiny entities, and thus also the objects composed of them. These laws were completely independent of whether anyone was observing the physical universe or not. Those earlier laws took no special cognizance of any acts of observation performed by human beings, or of any knowledge acquired from such observations, or of the conscious thoughts of human beings. All such things were believed to be completely determined at a microscopic level by purely physical properties. However, the baffling features of new kinds of data acquired during the twentieth century caused the physicists who were studying these phenomena, and trying to ascertain the laws that governed them, to turn the whole scientific enterprise upside down.

Perhaps I should say that they turned what had been upside down rightside up. For the word "science" comes from the Latin word scire, "to know," and what the quantum physicists claimed, basically, is that the proper subject matter of science is not what may or may not be "out there," unobserved and unknown to human beings. It is rather what we human beings can know. Thus they formulated their new theory, called quantum mechanics, or quantum theory, around the knowledge-acquiring actions of human beings and the knowledge acquired from these actions, rather than around some imagined-to-exist world "out there". The whole focus of the theory was thus shifted from one that basically ignored our knowledge to one that is, in the final analysis, about the structural properties of our knowledge.

This shift did not amount merely to looking at the same old physical world from a new point of view. Rather the whole landscape was transformed into something so strange and unfamiliar that it seemed to be understandable only in terms of how it worked for us: of how we *use* it.

This modified conception of science differs from the old one in many fascinating ways that continue to absorb the interest of physicists. However, it is the revised understanding of the basic nature of human beings, and of the causal role of human consciousness in the unfolding of reality, that is, I believe, the most exciting thing about the new physics, and probably, in the final analysis, also the most important contribution of science to the well-being of our species.

The new theory, quantum theory, accounts in a uniform manner for all the observed successes of the earlier physical theories, and also for the immense accumulation of new data for which the earlier methods fail abysmally. But it describes a world built not out of bits of matter, as matter was understood in the nineteenth century, but rather out of a fundamentally different kind of stuff. According to the revised notion, physical reality behaves more like spatially encoded information that governs *tendencies* for experiential events to occur, than like anything resembling material substance.

Moreover, according to this new understanding, the world is governed not by one single uniform process, but by several very different complementary processes, only one of which is analogous to the mechanical process described by classical physics. The quantum counterpart of the mechanical process of classical physics is the part of the new theory of main interest to physicists, engineers, and other workers not concerned with the mental side of reality. But anyone interested in the role in nature of our conscious thoughts, ideas, and feelings needs to understand the other processes, because it is those other processes that allow our conscious thoughts to affect our physical actions.

Nothing like this action of mind upon physically described things exists in classical physics. Indeed, there is nothing in the principles of classical physics that requires, or even hints at, the existence of such things as thoughts, ideas, and feelings, and certainly no rules that dictate how the idea-like aspects of nature influence the physical aspects. Indeed, it was precisely the absence in classical physics of any notion of experiential-type realities, or of any job for them to do, or of any possibility for them to do anything not already done by the tiny mechanical elements, that has been the bane of philosophy for three hundred years. Now, however, that material conception of nature, which was the root of so much philosophical dispute, has been found to be fundamentally false. It has been replaced by a radically different framework that not only reproduces all the verified results of the prior theory and the immense accumulation of new data, but also brings our conscious thoughts into the causal structure.

The new theory, unlike the old one, gives our conscious choices an essential role to play in the unfolding of reality. In orthodox quantum theory the action of our minds does not redundantly over-determine things already fully fixed by the physical laws. Instead, it partially fills a causal gap in the physically described dynamical rules. That causal gap in the physical laws was opened up by a principle of uncertainty that lies at the conceptual heart of the new physics.

The original “Copenhagen” formulation of quantum theory is the official doctrine. It is what is used in actual practice. It is formulated as a set of rules to be used by physicists as they go about their jobs of collecting data and making predictions. It is a set of practical rules that allow physicists to compute predictions about what the observed responses to their freely chosen probing actions are likely to be.

There is a tremendous difference between this new physical theory and the classical physical theory that it supercedes. The older theory was about tiny bits of matter, and how their behaviours were governed by the effects of neighboring bits. The new theory is about bits of information or knowledge that we can acquire by performing appropriate actions. It is about the freedom provided by the theory for us to choose which actions we will take---and when we will take them---and about the knowledge obtained from the observed responses to these actions.

I shall begin my account of these developments in science by emphasizing, in the words of the founders themselves, the central role played in the new theory by “our knowledge.”

2. Human Knowledge as the Foundation of Science .

What are you made of? What is reality made of? What does intuition say about this? What does science say?

The deliverance of intuition on these matters is not unambiguous. Western science and philosophy begins with Thales of Miletus, who proclaimed "All is Water!” Other Greeks believed the primordial stuff to be "Air", or "Earth", or "Fire", and Empedocles settled on all four. On the other hand, Leucippus and Democritus thought everything was composed of tiny invisible, immutable atoms. Two millennia later, it looked like the two atomists had gotten it right: Isaac Newton built his seventeenth-century theory of the universe on the idea of localized bits of matter, and John Dalton's atomic hypothesis explained many facts of chemistry.

This notion that everything is composed of small localized bits of matter encounters, however, a serious difficulty. The earlier idea that "air" was a primary ingredient allowed our conscious thoughts to be construed as constructed out of one of the primitive substances. But it was hard to see how such a thing as a sensation of the color "red" or "green", or a feeling of "pain" or "joy" could be fully described in terms of a collection of tiny immutable bits of matter careening through space. Given even supreme knowledge and comprehension, how could the motions of billions of particles in a person's brain/body be understood to produce, or be the very same thing as, a conscious sensation, or the feeling associated with the grasping of an idea? One can understand all manner of motions of objects, and of their changing shapes, in terms of the motions of their tiny constituent parts, but there is a rationally unbridgeable conceptual gap between the purely geometrical concepts of motions of immutable atomic particles in space and the psychological realities of conscious sensations, feelings, ideas, and efforts. The classical-physics concept of “a collection of moving material particles” has, by definition, no entailed “experiential” property.

Isaac Newton built his theory upon the ideas of the French philosopher René Descartes, who resolved this dilemma concerning psychological realities by conceiving nature to be built out of two sorts of substances: "matter", which was located in and occupied space, and the "mental stuff" that our ideas, thoughts, sensations, feelings, and efforts are made of. This sundering of nature worked well in science for more than two hundred years, but was abandoned by physicists during the twentieth century. Once it became clear that the old mechanical notions could not account for the growing mountain of data concerning the properties of systems that depend sensitively on the properties of their atomic constituents the theoretical focus shifted from the idea of a material world existing “out there”, independently of our observations of it, to what the experiments were actually telling us. This opened the door to a new approach that dealt directly with our knowledge, rather than with a supposedly independently existing system itself. An incredibly beautiful and rationally coherent new kind of mathematical structure was eventually created. But this new mathematics described not a self-sufficient physical reality that exists independently of all minds, but rather a radically new kind of physical reality that represents, among other things, the evolving state of our knowledge, and also the tendencies, or propensities, for new acts of knowing to occur.

The original and official Copenhagen formulation of quantum theory is closely tied to actual experimental procedures. It is built around the activities of human experimenters who design and perform experiments with some purpose in mind, and who later record and interpret the results of their observations. This formulation has elements that are definitely subjective and even anthropocentric, being based on “our” (human) knowledge. Many physicists have sought to eliminate these subjective features. But those efforts, some of which will be described later, must preserve the connections to human knowledge specified by the founders if they are to retain the empirical content of the theory.

In the introduction to his book "Quantum theory and reality" the philosopher of science Mario Bunge (1967) said:

"The physicist of the latest generation is operationalist all right, but usually he does not know, and refuses to believe, that the original Copenhagen interpretation---which he thinks he supports---was squarely subjectivist, i.e., nonphysical."

Let there be no doubt about this point. The original form of quantum theory is subjective, in the sense that it is forthrightly about relationships among conscious human experiences, and it expressly recommends to scientists that they resist the temptation to try to understand the reality responsible for the correlations between our experiences that the theory correctly describes. The following brief collection of quotations by the founders gives a conspectus of the Copenhagen philosophy:

Heisenberg (1958a): "The conception of objective reality of the elementary particles has thus evaporated not into the cloud of some obscure new reality concept but into the transparent clarity of a mathematics that represents no longer the behaviour of particles but rather our knowledge of this behaviour."

Heisenberg (1958b): "...the act of registration of the result in the mind of the observer. The discontinuous change in the probability function…takes place with the act of registration, because it is the discontinuous change in our knowledge in the instant of registration that has its image in the discontinuous change of the probability function."

Heisenberg (1958b): "When the old adage `Natura non facit saltus' (Nature makes no jumps) is used as a basis of a criticism of quantum theory, we can reply that certainly our knowledge can change suddenly, and that this fact justifies the use of the term `quantum jump'. "

Wigner (1961): "the laws of quantum mechanics cannot be formulated...without recourse to the concept of consciousness."

Bohr (1934): "In our description of nature the purpose is not to disclose the real essence of phenomena but only to track down as far as possible relations between the multifold aspects of our experience."

Bohr (1963): "Strictly speaking, the mathematical formalism of quantum mechanics merely offers rules of calculation for the deduction of expectations about observations obtained under well-defined classical concepts."

Bohr (1958): "...the appropriate physical interpretation of the symbolic quantum mechanical formalism amounts only to prediction of determinate or statistical character, pertaining to individual phenomena appearing under conditions defined by classical physics concepts."

The references to "classical (physics) concepts" is explained in Bohr (1958): "...it is imperative to realize that in every account of physical experience one must describe both experimental conditions and observations by the same means of communication as the one used in classical physics."

Bohr (1958) "...we must recognize above all that, even when phenomena transcend the scope of classical physical theories, the account of the experimental arrangement and the recording of observations must be given in plain language supplemented by technical physical terminology."

Bohr is saying that scientists do in fact use, and must use, the concepts of classical physics in communicating to their colleagues the specifications on how the experiment is to be set up, and what will constitute a certain type of outcome. He in no way claims or admits that there is an actual objective reality out there that conforms to the precepts of classical physics.

In his book "The creation of quantum mechanics and the Bohr-Pauli dialogue" (Hendry, 1984) the historian John Hendry gives a detailed account of the fierce struggles by such eminent thinkers as Hilbert, Jordan, Weyl, von Neumann, Born, Einstein, Sommerfeld, Pauli, Heisenberg, Schroedinger, Dirac, Bohr and others, to come up with a rational way of comprehending the data from atomic experiments. Each man had his own bias and intuitions, but in spite of intense effort no rational comprehension was forthcoming. Finally, at the 1927 Solvay conference a group including Bohr, Heisenberg, Pauli, Dirac, and Born come into concordance on a solution that came to be called "The Copenhagen Interpretation", due to the central role of Bohr and those working with him at his institute in Denmark.

Hendry says: "Dirac, in discussion, insisted on the restriction of the theory's application to our knowledge of a system, and on its lack of ontological content." Hendry summarized the concordance by saying: "On this interpretation it was agreed that, as Dirac explained, the wave function represented our knowledge of the system, and the reduced wave packets our more precise knowledge after measurement."

These quotations make it clear that, in direct contrast to the ideas of classical physical theory, orthodox Copenhagen quantum theory is about “our knowledge.” We, and in particular our mental aspects, have entered into the structure of basic physical theory.

This profound shift in physicists’ conception of the basic nature of their endeavor, and of the meanings of their formulas, was not a frivolous move: it was a last resort. The very idea that in order to comprehend atomic phenomena one must abandon physical ontology, and construe the mathematical formulas to be directly about the knowledge of human observers, rather than about external “real” events themselves, is so seemingly preposterous that no group of eminent and renowned scientists would ever embrace it except as an extreme last measure. Consequently, it would be frivolous of us simply to ignore a conclusion so hard won and profound, and of such apparent direct bearing on our effort to understand the connection of our conscious thoughts to our bodily actions.

Einstein never accepted the Copenhagen interpretation. He said: "What does not satisfy me, from the standpoint of principle, is its attitude toward what seems to me to be the programmatic aim of all physics: the complete description of any (individual) real situation (as it supposedly exists irrespective of any act of observation or substantiation)." (Einstein, 1951, p.667: the parenthetical word and phrase are part of Einstein's statement.);

and “What I dislike in this kind of argumentation is the basic positivistic attitude, which from my view is untenable, and which seems to me to come to the same thing as Berkeley's principle, *esse est percipi*. (Einstein, 1951, p. 669). [Transl: To be is to be perceived]

Einstein struggled until the end of his life to get the observer’s knowledge back out of physics. He did not succeed! Rather he admitted that: "It is my opinion that the contemporary quantum theory constitutes an optimum formulation of the [statistical] connections." (ibid. p. 87).

He also referred to: "the most successful physical theory of our period, viz., the statistical quantum theory which, about twenty-five years ago took on a logically consistent form. This is the only theory at present which permits a unitary grasp of experiences concerning the quantum character of micro-mechanical events." (ibid p. 81).

One can adopt the cavalier attitude that these profound difficulties with the classical conception of nature are just some temporary retrograde aberration in the forward march of science. One may imagine, as some do, that a strange confusion has confounded our best minds for seven decades, and that the weird conclusions of physicists can be ignored because they do not fit our classical-physics-based intuitions. Or one can try to claim that these problems concern only atoms and molecules, but not the big things built out of them. In this connection Einstein said: "But the `macroscopic' and `microscopic' are so inter-related that it appears impracticable to give up this program [of basing physics on the `real'] in the `microscopic' domain alone." (ibid, p.674).

The quotations displayed above make clear the fact that Copenhagen quantum theory brings human consciousness into the theory in an essential way. The questions before us are these: How is this done? And how does this radical change in basic physics affect science’s conception of the human person?

Our principal concern here is the causal role of our minds in the determination of our actions: Are our physical actions completely controlled by mechanical processes that are fully specified by short-range interactions between tiny localized mechanical parts, or, on the other hand, are our actions influenced, irreducibly, by psychological realities? Are the activities of our brains completely determined by “bottom-up” processes---i.e., by contact interactions between tiny material elements? Or can there be also an essential “top-down” contribution: an effect of conscious mental activity, per se, that influences brain action in a way that is not a consequence of microscopic bottom-up processes alone?

According to orthodox quantum theory the answer to this final question is “Yes”! The immediate follow-up question is then: How can something having the character of an experiential or conscious reality enter rationally into the mathematical structure that describes the physical state of the brain? How does quantum theory resolve the core problem of philosophy, which is the apparent logical disconnect between our streams of conscious experiences, directly known to us, and the nature of the physical world as basic science conceives it?

The answer, in brief, is this: Quantum theory is constructed by replacing the “numbers” that describe the material world of classical physics by “actions”, and in this world of actions the psychological and physical aspects of reality are entities of the same kind, linked by mathematical laws! My aim here is to explain to non physicists, in a technically accurate but hopefully still lucid manner, how the causal binding of these apparently disparate realities is achieved.

3. Actions, Knowledge, and Information

The Anti-Newtonian Revolution

From the time of Isaac Newton until about 1925 science relegated consciousness to the role of passive viewer: our thoughts, ideas, and feelings were treated as impotent bystanders to a march of events wholly controlled by interactions between tiny mechanical elements. Conscious experiences, insofar as they had any influences at all on what happens in the physical world, were thought to be completely determined at the microscopic level by the motions of miniscule entities. Hence the experiential felt realities that make up our streams of consciousness were regarded as either irrelevant to physics or redundant, and were denied fundamental status in the basic theory of physics.

The founders of quantum mechanics made the revolutionary move of bringing conscious human experiences into basic physical theory in a fundamental way. In the words of Niels Bohr, the key innovation was to recognize that "in the great drama of existence we ourselves are both actors and spectators." (Bohr, 1963, p. 15: 1958, p. 81) After two hundred years of neglect, our thoughts were suddenly thrust into the limelight. This was an astonishing reversal of precedent because the enormous successes of the prior physics were due in large measure to the policy of excluding all mention of idea-like qualities from the formulation of the physical laws.

What sort of crisis could have forced the creators of quantum theory to make this radical innovation of injecting mind explicitly into the basic laws of physics? The answer to this question begins with a discovery that occurred near the beginning of the twentieth century. In December of the year 1900 Max Planck discovered and measured the "quantum of action.” Its measured value is called "Planck's Constant." This constant specifies one of three basic quantities that are built into the fundamental fabric of the physical universe. The other two are the gravitational constant, which fixes the strength of the force that pulls every bit of matter in the universe toward every other bit, and the speed of light, which controls the response of every particle to this force, and to every other force. The integration into physics of each of these three basic quantities generated a monumental shift in our conception of nature.

Isaac Newton discovered the gravitational constant, which linked our understandings of celestial and terrestrial dynamics. It connected the motions of the planets and their moons to the trajectories of cannon balls here on earth, and to the rising and falling of the tides. Insofar as his laws are complete the entire physical universe is governed by mathematical equations that link every bit of matter to every other bit, and moreover fix the complete course of history for all times from physical conditions prevailing in the primordial past.

Einstein recognized that the "speed of light" is not just the rate of propagation of some special kind of wave-like disturbance, namely "light". It is rather a fundamental number that enters into the equations of motion of every kind of material substance, and, among other things, prevents any piece of matter from traveling faster than this universal maximum value. Like Newton's gravitational constant it is a number that enters ubiquitously into the basic structure of Nature.

But important as the effects of these two quantities are, they are, in terms of profundity, like child's play compared to the consequences of Planck's discovery.

Planck's "quantum of action" revealed itself first in the study of light, or, more generally, of electromagnetic radiation. The radiant energy emerging from a tiny hole in a heated hollow container can be decomposed into its various frequency components. Classical nineteenth century physics gave a prediction about how that energy should be distributed among the frequencies, but the empirical facts did not fit that theory. Eventually, Planck discovered that the empirically correct formula could be obtained by assuming essentially that the energy was concentrated in finite packets, with the amount of energy in each such unit being directly proportional to the frequency of the radiation that was carrying it. The ratio of energy to frequency is called "Planck's constant". Its value is extremely small on the scale of normal human activity, but becomes significant when we come to the behaviour of the atomic particles and fields out of which our bodies, brains, and all large physical objects are made.

Planck’s discovery shattered the classical laws that had been the foundation of the scientific world view. During the years that followed many experiments were performed on systems whose behaviours depend sensitively upon the properties of their atomic constituents. It was repeatedly found that the classical principles did not work: they gave well defined predictions that turned out to be flat-out wrong, when confronted with the experimental evidence. The fundamental laws of physics that every physics student had been taught, and upon which much of the industrial and technological world of that era was based, were failing. More importantly, and surprisingly, they were failing in ways that no mere tinkering could ever fix.

Something was fundamentally amiss. No one could say how these laws, which were so important, and that had seemed so perfect, could be fixed. No one could foresee whether a new theory could be constructed that would explain these strange and unexpected results, and restore rational order to our understanding of nature. But one thing was clear to those working feverishly on the problem: Planck's constant was somehow at the center of it all.

The World of Actions

Werner Heisenberg was, from a technical point of view, the principal founder of quantum theory. He discovered in 1925 the completely amazing and wholly unprecedented solution to the puzzle: the quantities that classical physical theory was based upon, and which were thought to be numbers, must be treated not as numbers but as actions! Ordinary numbers, such as 2 and 3, have the property that the product of any two of them does not depend on the order of the factors: 2 times 3 is the same as 3 times 2. But Heisenberg discovered that one could get the correct answers out of the old classical laws if one decreed that certain numbers that are used in classical physics to describe the physical properties of a material system are not ordinary numbers. Rather, they are actions having the property that the order in which they act matters!

This "solution" may sound absurd or insane. But mathematicians had already discovered that logically consistent generalizations of ordinary mathematics exist in which numbers are replaced by "actions" having the property that the order in which they are applied matters. The ordinary numbers that we use for everyday purposes like buying a loaf of bread or paying taxes are just a very special case from among a broad set of rationally coherent mathematical possibilities. In this simplest case, A times B happens to be the same as B times A. But there is no logical reason why Nature should not exploit one of the more general cases: there is no compelling reason why our physical theories must be based exclusively on ordinary numbers rather than on actions. The theory based on Heisenberg's discovery exploits the more general logical possibility. It is called quantum mechanics, or quantum theory.

The difference between quantum mechanics and classical mechanics is specified by Planck's constant, which is a tiny number on the scale of human actions. Thus this tweaking of laws of physics might seem to be a bit of mathematical minutia that could scarcely have any great bearing on the fundamental nature of the universe, or of our role within the universe. But replacing *numbers* by *actions* upsets the whole apple cart. It produces a seismic shift in our ideas about both the nature of reality, and the nature of ourselves. The world of *material substances* is converted to a world of *mathematical actions*, *and* their counterparts in the world of *our conscious experiences*. Our conscious thoughts become engaged in ways that cannot be implemented within the mechanical framework of classical physics.

What is this change introduced by Heisenberg?

In classical physics the center-point of each physical object has, at each instant of time, a well defined location, which can be specified by giving its three coordinates (x, y, z) relative to some coordinate system. For example, the location of a spider dangling in a room can be specified by letting z be its distance from the floor, and letting x and y be its distances from two intersecting walls. Similarly, the velocity of that dangling spider, as she drops to the floor, blown by a gust of wind, can be specified by giving the rates of change of these three coordinates (x, y, z). If each of these three rates of change, which together specify the velocity, are multiplied by the weight (=mass) of the spider, then one gets three numbers, say (p, q, r), that define the "momentum" of the spider. In classical physics one uses the set of three numbers denoted by (x,y,z) to represent the position of the center point of an object, and the set of three numbers called (p,q,r) to represent the momentum of that object. These are just ordinary numbers that obey the commutative property of multiplication that we all, hopefully, learned in 3rd grade: x*p equals p*x, where * means multiply.

Heisenberg's analysis showed that in order to make the formulas of classical physics describe quantum phenomena, x*p must be different from p*x. He found that the difference between these two products must be Planck's constant. [Actually, the difference is Planck's constant divided by 2π and multiplied by the imaginary unit i, which is a number such that i times i is minus one.] Thus modern quantum theory was born by recognizing, or declaring, that the symbols used in classical physical theory to represent ordinary numbers actually represent actions such that their ordering in a sequence of actions is important. The procedure of creating the mathematical structure of quantum mechanics from that of classical physics, by replacing numbers by corresponding actions, is called "quantization."

The idea of replacing the numbers that specify where a particle is, and how fast it is moving, by mathematical quantities that violate the simple laws of arithmetic may strike you---if this is the first you've heard about it---as a giant step in the wrong direction. You might mutter that scientists should try to make things simpler, rather than abandoning one of the things we really know for sure, namely that the order in which one multiplies factors does not matter. But against that intuition one must recognize that this change works beautifully in practice: all of the tested predictions of quantum mechanics are borne out, and these include predictions that are correct to the incredible accuracy of one part in a hundred million. There must be something very very right about this replacement of numbers by actions.

Quantum mechanics, like classical mechanics, uses mathematics to make predictions about empirical phenomena. To connect phenomena to mathematics there must be links between certain features of the mathematics and corresponding features of empirical phenomena. It is plausible that mathematical *actions* should correspond to physical *actions*, and this turns out to be the case.

The mathematical action x is associated with a certain physical probing action. A physical probing action is an action that elicits a response, called an outcome or a feedback. The probing action associated with the mathematical action x is one such that the feedback would be the number x that (together with the analogous numbers y and z) would specify the location of (the center of) the object being probed, provided the location of (the center of) that object is well defined. The action p is defined analogously. Those two particular physical actions exist only as idealized limits of physically realizable probing actions. Indeed, many of the actions occurring in the mathematics do not correspond to physically realizable probing actions. On the other hand, every physically realizable probing action corresponds to some mathematical action.

The profound significance of this is that Heisenberg's replacement of numbers by mathematical actions is associated with a huge conceptual change. *The basic elements of classical theory, which are <u>numbers that specify</u> <u>internal properties</u> <u>of a system</u>, <u>are replaced by probing actions performed upon that system by an "observing" system lying external to it.</u>* Thus probing actions performed by *observers* situated *outside the physically described system* are injected directly into the mathematical and conceptual core of the theory! Each such action has an aspect described in the language of the quantum mathematics and also an aspect described in terms of the experiences of the probing agents! Human experiences are thereby brought into the basic framework of physics in a causally efficacious, non-redundant, and pragmatically useful way that has been extensively tested and validated to high precision.

Probing actions play a key role in quantum mechanics. The orthodox formulation of the theory asserts that, in order to connect the mathematically described state of a physical system to human experience, there must be abrupt *interventions* in the otherwise smoothly evolving mathematically described state of that system. According to the orthodox formulation, these interventions are probing actions *instigated by human agents who are able to freely choose which of many alternative possible probing actions they will perform*. Each possible probing action divides the physical state of the system being probed into a corresponding set of disjoint component parts, one associated with each of the possible outcomes of that probing action. If an allowed probing action is performed, then one of its allowed feedbacks will appear, and the mathematically described state of the probed system will jump abruptly from the form it had prior to the intervention to the component part of that state corresponding to the observed feedback. *This means that, according to orthodox contemporary physical theory, the "free" choices of probing actions made by agents enter importantly into the course of both the ensuing psychologically described events, and the ensuing physically described events.*

This scenario involving free choices and sudden jumps may seem to you completely bizarre. Indeed, it *is* completely bizarre from the perspective of the classical idea of the nature of the physical world. Nevertheless, *this is exactly how orthodox quantum mechanics actually works!*

This scenario is not so strange from the point of view of Descartes. According to the ideas of Descartes there is, in effect, a psychologically described aspect of nature and also a physically described aspect, and these two aspects interact with each other according to some rules. These rules must allow the *psychologically described* part both to *learn things* about the *physically described* part, and also to *influence* it. These two key conditions are neatly satisfied in the quantum scenario, in which the probing agent's free choice of which probing action to perform affects the course of both the physically described and psychologically described sequence of events.

If one sets Planck's constant equal to zero in the quantum mechanical equations then one recovers (the physically incorrect) classical mechanics. Thus classical physics is *an approximation* to quantum physics. It is the approximation in which Planck's constant, wherever it appears, is replaced by zero. In this approximation one recovers classical physics, along with the physical determinism entailed by classical physics.

Using the true value of this constant---measured in 1900 by Planck---disrupts classical equations and renders the classically conceivable universes physically unrealizable. The allowed quantum states are, roughly, smeared out versions of the old classically described states, with the *minimum* allowed amount of smearing being specified by Planck's constant. This intrinsic smearing, the so-called Heisenberg uncertainty, shrinks to zero in the classical approximation. Thus this approximation pares the smeared out state down to a single unsmeared classical state.

It is the Heisenberg uncertainty that creates the logical opening, or space, within which the interventions of the causally efficacious probing actions operate. The Heisenberg smearing out of the quantum state provides *the latitude within which the chosen probing action acts.* Each possible outcome of any allowed probing action corresponds to *one* of a set of *disjoint component parts* of the smeared out quantum state.

The particular way in which these disjoint component parts are carved out of the smeared-out quantum state is selected by *the observer's choice* of probing action. After a probing action is initiated, one of these specified component parts of the smeared out state will be <u>actualized</u>, and all others banished, by some yet-to-be-understood process of nature. In the classical approximation, on the other hand, there is no need for, *and also no room for*, any effects of a probing action. The *uncertainties* that in the full theory need to be resolved by the intervention of a probing action are already reduced to zero by the replacement of Planck's constant zero. Thus all effects on the physically described aspects of nature due to the actions chosen by agents are eliminated when one employs the classical approximation. *Hence the physical efficacy of our conscious choices is, within the framework of orthodox contemporary physical theory, strictly a quantum effect. The* *physical efficacy of our conscious choices completely vanishes in the classical approximation.*

In view of this fact, it would appear that, insofar as one accepts the validity of orthodox contemporary physics, all of the contemporary programs that try to understand the empirically observed physical effects of consciousness within the framework of the classical approximation are irrational endeavour*s, simply because the approximation being employed eliminates the effect one is trying to study.*

The classical approximation works well in many situations. But it is unable in principle to account adequately for the observed *macroscopic* behaviours of large physical systems whose macroscopic behaviours depend sensitively upon the behaviours of their atomic constituents. To comprehend the macroscopic behaviours of large systems of this kind one must, in general, use quantum theory.

According to the orthodox interpretation of quantum theory, the interventions of our consciously chosen (probing) actions are “freely chosen” in the very specific sense that they are *not determined by any known law of physics*. Yet these actions can affect physically described properties. This conjunction of conditions severs in one stroke the dogma of mechanical determinism that has perplexed and hobbled philosophy for three centuries: *twentieth century advances in physics have freed philosophy and psychology from the yoke of the doctrine of the causal closure of the physical.*

Orthodox contemporary physics leads on, in a completely natural and rational way, to a theory of the mind-brain system that appears to accommodate neatly the empirical data that, on their face, indicate an effect of our conscious choices on the physically described activities of our brains. In this model the conscious choices actually do what they appear to us to be doing. They are neither redundant, ineffectual, nor illusory. But before moving on to an account of that development I shall flesh out the compact bare-bones account just given of the nature of quantum mechanics.

<u>Intentional Actions and Experienced Feedbacks</u>

Quantum theory is built upon the idea of intentional actions by agents. Each such action is intended to produce an experiential response or feedback. For example, a scientist might act to place a Geiger counter near a radioactive source, with the intention to see the counter either “fire” during a certain time interval or not “fire” during that interval. The experienced response, “Yes” or “No”, to the question “Does the counter fire during the specified interval?” specifies one bit of information. Quantum theory is built around such knowledge-acquiring actions of agents, and the knowledge that these agents thereby acquire.

Probing actions of this kind are performed not only by scientists. Every healthy and alert infant is engaged in making willful efforts that produce experiential feedbacks, and he or she soon begins to form expectations about what sorts of feedbacks are likely to follow from some particular kind of felt effort. Thus both empirical science and normal human life are based on paired realities of this action-response kind, and our physical and psychological theories are both basically attempts to understand these linked realities within a rational conceptual framework.

As another example, consider a single physical object, such as the dangling spider mentioned above, and the set of three numbers x, y, and z that according to the ideas of classical physics specify where the (center of the) object is located. According to quantum theory, no one can ever find out exactly where this center point lies. Accordingly, quantum theory deems superfluous the notion that (the center of) each object or particle has a well defined location. Thus the new theory can use the symbols x, y, and z that in classical physics represent the three numbers that locate the (center of the) object to represent three other things, namely three corresponding actions, x, y, and z. These actions are associated with the probing action of acquiring knowledge pertaining to the location of the object.

Although no one can ever know *exactly* where the spider is located, a human agent can, by a willful effort, initiate a purposeful action that normally will produce an experiential feedback that can be conceived to provide *some* information pertaining to the location the spider. For example, one may, by an appropriate willful act, direct one's visual attention to the task of determining whether the spider appears to move during a certain time interval or, instead, appears to remain stationary. Or one might endeavour to learn whether the spider appears to stay in her web during that interval or not. One bit of information will be supplied by the experienced answer to either one of these Yes-or-No queries.

Inquiring action and empirical feedbacks are natural components of any developmental theory.

Doing useful experiments depends on someone's being able to distinguish experiences that meet specified criteria from those that do not. Someone must be able to say whether an experience of the Geiger counter firing occurred or not. Science, as we know it, would be difficult to pursue if scientists could make no judgments about the character of the feedbacks from their probing actions. The basic move in quantum theory is to descend from the airy plane of high-level abstractions, such as precise trajectories of unseen and unseeable elementary material particles, to the level of more nitty-gritty realities: consciously chosen intentional actions and experienced feedbacks of specified kinds, and to the creation of mathematical procedures that predict relationships among such empirical realities.

A purposeful action by a human agent has two aspects. One aspect is his conscious intention, which is described in psychological terms. The other aspect is the linked physical action, which is described in physical terms; i.e., in terms of mathematical entities assigned to space-time points. The physically described action must be a *functional counterpart* of the conscious intention. After honing it must tend to produce, in the physically described world, what the thought intends. More precisely, it must tend to produce in the stream of consciousness of the agent a feedback that confirms that the intention has been achieved. This matching of psychologically described intentional actions to physically described functional counterparts is achieved by trial-and-error learning. It is absolutely essential to the notion of trial and error learning that the consciously experienced choices be physically efficacious: they must *do* something! Quantum mechanics meets this condition, but the classical approximation, by eliminating the physical latitude introduced by the uncertainty principle, squeezes our conscious choices out of the causal chain described by the more accurate full theory.

Key elements of quantum theory, then, are a set of purposeful actions by agents, and for each such action an associated possible experiential feedback “Yes”, which is a response that the agent can judge to conform to the criterion of *success* associated with that purposeful act. A failure of this ‘Yes’ response to occur is classified as ‘No’.

For example, if the agents acts to determine whether the spider stays in its web, then the agent is expecting a feedback that will allow him or her to make the judgment “Yes” the spider stayed in its web or “No” the spider did not stay in its web.

[More complex inquiries with several alternative responses are possible, but it is enough to consider just the simple “Yes” or “No” cases. A multiple choice query can be decomposed into a sequence: Is it the first? Is it the second? Is it the third? …]

All known physical theories involve idealizations of one kind or another. The main idealization in quantum theory is not that every object is made up of miniature planet-like objects. It is rather the far more empirically secure assumption that there are agents that perform intentional acts each of which can result in an experiential feedback that may or may not conform to an experiential criterion associated with the successful achievement of that intention. One bit of information is introduced into the agent’s stream of consciousness, according to whether the feedback conforms or does not conform to that criterion. Thus finding out whether the spider moved or not places the agent on one or the other of two alternative possible distinct branches of the course of world history, at least insofar as effects of that world enter into the agent’s stream of consciousness.

John von Neumann, in his seminal book, *Mathematical Foundations of Quantum Mechanics*, calls this basic probing action by the name “Process 1”, and I shall adopt that terminology. A Process 1 probing action consists of a conscious intention to act in a certain way coupled with an associated physically described *intervention* in the orderly mechanical evolution of the probed system. Von Neumann calls this orderly mechanically controlled evolution by the name Process 2. It is specified by the quantization procedure. But there are also two other associated processes that deserve names. The first of these is the process that selects the outcome, Yes’ or ‘No’, of the probing action. I shall call this *choice on the part of nature* by the name

Process 3. The Process 3 selection of the answer/outcome is subject to known quantum statistical rules. Finally, there is the process that fixes or determines what the occurring Process 1 action will be. Process 1 *itself* is an integral part of orthodox quantum theory, but no conditions are imposed by orthodox quantum mechanics on how the Process 1 choice turns out to be what it turns out to be. Within orthodox quantum theory this choice is not subject to any known law. Yet this choice fixes the form Process 1, which has direct physical consequences. I shall call by the name *Process 4* the process, whatever it is, that determines the form of the occurring Process 1. The absence of any specifications on the workings of Process 4 constitutes a causal gap in contemporary orthodox physical theory.

My primary aim in this book is alert readers to the scientific, philosophical, and moral significance of the existence within contemporary orthodox physical theory of the Process 1 conscious choices, and then to expand upon von Neumann's orthodox development of the work of the founders of quantum mechanics by making and defending some philosophically motivated and empirically supported proposals about the Process 4 determinations of the causally efficacious Process 1 actions.

The mathematical machinery needed to accommodate the switch from classical to quantum physics involves passing from a description of nature imbedded in ordinary four-dimensional space-time to a description imbedded in a "Hilbert Space" of an infinite number of dimensions. But my intention here is to get at the essential *conceptual* issues without burdening the reader with an account of the mathematical technicalities.

Free Choices

Orthodox quantum theory is formulated in a realistic and practical way. It is structured around the activities of human agents, who are considered able to freely choose to probe nature in any one of many possible ways. Bohr emphasized the freedom of experimenters in passages such as:

> "The freedom of experimentation, presupposed in classical physics, is of course retained and corresponds to the free choice of experimental arrangement for which the mathematical structure of the quantum mechanical formalism offers the appropriate latitude." (Bohr, 1958, p.73)
>
> "To my mind there is no other alternative than to admit in this field of experience, we are dealing with individual phenomena and that our possibilities of handling the measuring instruments allow us only to make a choice between the different complementary types of phenomena that we want to study. (Bohr, 1958, p. 51)

This theoretical freedom of action stems from the fact that in the original Copenhagen formulation of the theory the human experimenter stands outside the system to which the quantum laws apply. Those laws are the only precise laws the theory recognizes. Thus, according to Copenhagen philosophy, *the presently known laws* do not fix the choices made by the agent about how his probing action is to proceed. Those choice are, *in this very specific sense*, “free choices.”

Bohr’s assertion that the freedom of experimentation is “supposed in classical; physics” fingers the basic paradox of classical physics. That theory asserts that there is no such freedom: it asserts that our every act was fixed already at the beginning of time by immutable physical laws. Yet our entire lives are based on the idea that we are free to choose many of our actions. The thrust of this book is that this paradox is the direct consequence of embracing a false physical theory. The paradox is satisfactorily resolved not by labeling the most profound and enduring of all human experiences to be either an illusion, or some mysterious effect that will “one day” be understood. It can be resolved in a natural, naturalistic, and non-mysterious way by applying the applicable orthodox contemporary physical theory.

Copenhagen philosophy divides objects of scientific interest into observed systems and observing systems, and speaks of them in very different ways. The former are described are terms of the mathematical actions (operators) mentioned above, while the latter are described in terms of ordinary experience---refined by the concepts of *classical* physics.

This bifurcation of the subject matter into “observer” and “observee” works wonderfully in practice. But any chopping of the single unified physical world into parts described in different languages is bothersome to scientists who, desiring more than just successful rules, seek a rationally coherent understanding of what is actually going on.

Von Neumann evaded this unnatural splitting by including the entire physical world---including the bodies and brains of the human agents---in the part that is described in terms of the quantum mathematics. In this formulation the brain of the agent becomes the directly probed physical system: each Process 1 intentional act of the agent is physically represented by an abrupt change in the physical state of his or her brain. Process 1 changes the physical state of the brain in a way that *specifies the set of mutually exclusive possibilities open for the Process 3 choice*. This latter choice *on the part of nature* then chooses of one of these possibilities. Von Neumann’s formulation thereby provides a foundation, based on *contemporary* physics, for a theory of the causal connection between the mind and the brain. We shall see that this theory can be tied directly in a highly structured way to the empirical data of contemporary neuroscience and psychology.

Von Neumann’s formulation. by itself, does not resolve either of the following two “free choice” issues: (1), *which* of all the logically possible Process 1 actions will the agent choose to perform, and (2), *when* will the agent choose to perform this action.

Both of these choices are undetermined in the Copenhagen version of quantum mechanics, and are left undetermined also in von Neumann's development of it. No rule or law that fixes either of these two choices is given either by Copenhagen quantum theory or by von Neumann's orthodox development of it.

Although von Neumann's formulation still contains these two causal gaps, and hence fails to specify *completely* the form of the connection between mind and brain, it does provide a contemporary-physics-based framework upon which to construct a more complete theory. I shall in subsequent chapters propose a way to close *partially* these two gaps in a way that produces a rationally coherent theory of the mind-brain that appears to be in good accord with the facts and requirements of psychology, neuroscience, neuropsychology, and philosophy of mind. However, one of the most essential points of this book has already been made. The laws of orthodox contemporary physical theory require a certain process---called Process 1 by von Neumann---that produces, in general, a causal effect of your conscious "free choices" upon the physically described world. In von Neumann's formulation this effect is a causal consequence of your conscious choices upon your physically described brain. *Thus developments in basic physics during the twentieth century have nullified, as a rock-solid edict of science, the principle of the causal closure of the physical.* That doctrine, which has for over three centuries frustrated science-based attempts to understand the role in nature of our conscious thoughts, is not entailed by orthodox contemporary physical theory.

The situation, in short, is this. According to classical mechanics, everything that happens in the physical world is determined by a single bottom-up (i.e. working upward from atomic foundations) local-deterministic physical process, and hence we ourselves are, consequently, mechanical automata. This does not mean that in classical physics the high-level processes can have no effect on low-level processes. Certainly the behaviours of macroscopic entities such as wheels, pistons, and weather patterns have important causal consequences: high-level processes can certainly causally influence the course of low-level events. But in classical mechanics those top-down processes are simply re-expressions of certain features of the basic bottom-up process, which is dynamically complete within itself. In orthodox von Neumann quantum theory, on the other hand, the actions of human agents are governed jointly by several processes. One of them is the bottom-up local deterministic process that arises from Heisenberg's procedure of quantizing the classical laws of motion. This process, called Process 2 by von Neumann, is, like its classical counterpart, controlled by deterministic laws that are, moreover, *local*: everything is determined by interactions between elements that, on the one hand, are localized at space-time points, and, on the other hand, are influenced only by their immediate neighbors. This Process 2 specifies the way the quantum state of a system *usually* changes (continuously) with the passage of time. But this Process 2 action, by itself, does not yield any predictions concerning relationships between human experiences. Another process, namely Process 1, is needed. At certain instants of time the orderly evolution of the system in accordance with Process 2 is interrupted. A Process 1 action intervenes. This Process 1 intervention is associated with a probing action. This action is a genuine top-down process, in the sense that it originates---at least as far as orthodox contemporary physics can say---in a “freely chosen” intentional impulse, and its physical form reflects that intention. Moreover, this Process 1 intervention is non-local: it acts *all at once* over a macroscopic region. The currently known laws determine only the Process 2 mechanical development. They do not determine which of the many possible Process 1 actions actually occurs. Each agent has, within orthodox quantum theory, conscious “free choices”, and these free choices, by fixing which probing actions are performed, and when they are performed, have physical effects in the brain. Thus quantum mechanics, unlike classical mechanics, is intrinsically equipped to yield bona fide top-down macroscopic effects of conscious choices upon the mathematically described quantum states of physical systems.

Cloudlike Forms

The quantum state of a single elementary particle can be visualized, roughly, as a cloudlike structure consisting of a set of numbers that evolves in time and that represent, at each instant---for each region in a set of small non-overlapping regions into which (an appropriate) space can be divided---the probability of “finding” the particle in that region, *provided* one performs the particular probing action of asking in which one of those specified regions the particle lies. Nature responds to that query by answering ‘Yes’ for just one of these regions and ‘No’ for the rest. The information gleaned from this response depends upon what question was posed: on how the associated space is divided into these cells; and when the question is asked. The experienced feedback is accompanied by an abrupt reduction of the prior physical state of the probed system to a new state concordant with that feedback.

Simple Harmonic Oscillators

One of the most important and illuminating examples of this cloudlike feature of the quantum state is the one corresponding to a pendulum, or more precisely, to what is called a “simple harmonic oscillator.” Such a system is one in which there is a restoring force that tends to push the center point of the object to a single “base point” of lowest energy, and in which the strength of this restoring force is directly proportional to the distance of the center point of the object from this base point.

According to classical physics any such system has a state of lowest energy. In this state the center point of the object lies motionless at the base point. In quantum theory this system again has a state of lowest energy. But it is not localized at the base point. It is a cloudlike spatial structure that is spread out over a region that extends to infinity. However, the probability distribution represented by this cloudlike form has the shape of a bell: it is largest at the base point, and falls off in a prescribed manner as the distance of the center point from the base point increases.

If one were to squeeze this state of lowest energy into a more narrow space, and then let it loose, the cloudlike form would explode outward, but then settle into an oscillating motion. Thus the cloudlike spatial structure behaves rather like a swarm of bees, such that the more they are squeezed in space the faster they move relative to their neighbors, and the faster the squeezed cloud will explode outward if the squeezing constraint is released. This “explosive” property of narrowly confined states plays a key role in quantum brain dynamics, as we shall soon see.

The double-slit experiment

There is an important difference between the behaviour of the quantum cloudlike form and the somewhat analogous probability distribution of classical statistical mechanics. This difference is exhibited by the famous double-slit experiment. If one shoots an electron, a calcium ion, or any other quantum counterpart of a tiny classical object, at a narrow slit then if the object passes through the slit the associated cloudlike form will fan out over a wide angle. But if one opens two closely neighboring narrow slits, then what passes through the slits is described by a probability distribution that is not just the sum of the two separate fanlike structures that would be present if each slit were opened separately. Instead, at some points the probability value will be twice the *sum* of the values associated with the two individual slits, and in other places the probability value drops nearly to zero, even though both individual fanlike structures give a large probability value at that place. This non-additivity---or interference---property of the quantum cloudlike structure makes that structure very different from a probability distribution of classical physics, because in the classical case the probabilities arising from the two individual slits simply add.

This non-additivity property, which holds for a quantum particle such as an electron or a calcium ion, persists even when the particles come one at a time! According to *classical* ideas each tiny individual object must pass through either one slit or the other, so the probability distribution should be just the sum of the contributions from the two separate slits. But this is not what happens empirically. Quantum mechanics deals consistently with this property, and with all the other non-classical properties, of these cloudlike structures.

4. Nerve Terminals and the Need to Use Quantum Theory

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Many neuroscientists who study the relationship of consciousness to brain process want to believe that classical physics will be adequate for that task. But whether or not the classical approximation is applicable must be determined by examining the details of the physical situation, within the framework of the more general theory, to see whether the use of the classical approximation is justified. The technical question is: How important *quantitatively* are the effects of the uncertainly principle.

The need for, *and the room for*, quantum effects exists only to the extent that the smear of possibilities generated by the uncertainty principle *needs* to be reduced by the intervention of Process 1 actions. To answer this quantitative question we turn to an examination of the dynamics of nerve terminals.

Nerve Terminals

Nerve terminals lie at the junctions between two neurons, and mediate the functional connection between them. Neuroscientists have developed, on the basis of empirical data, fairly detailed classical models of how these important parts of the brain work. According to the classical picture, each "firing" of a neuron sends an electrical signal, called an action potential pulse, along its output fiber. When this signal reaches the nerve terminal it opens up tiny channels in the terminal membrane, through which calcium ions flow into the interior of the terminal. Within the terminal are "vesicles", which are small storage areas containing chemicals called neurotransmitters. The calcium ions migrate by diffusion from their entry channels to special sites, where they trigger the release of the contents of a vesicle into a gap between the terminal and a neighboring neuron. The released chemicals influence the tendency of the neighboring neuron to fire. Thus the nerve terminals, as connecting links between neurons, are basic elements in brain dynamics.

The channels through which the calcium ions enter the nerve terminal are called "ion channels". At their narrowest points they are only about a nanometer in width, hence not much larger than the calcium ions themselves. This extreme smallness of the opening in the ion channels has profound quantum mechanical import. The consequence is essentially the same as the consequence of the squeezing of the state of the simple harmonic oscillator, or of the narrowness of the slits in the double-slit experiments. The narrowness of the channel restricts the lateral spatial dimension. Consequently, the uncertainty in lateral velocity is forced by the quantum uncertainty principle to become non-zero, and to be in fact about 1% of the longitudinal velocity of the ion. This causes the quantum probability cloud associated with the calcium ion to fan out over an increasing area as it moves away from the tiny channel to the target region where the ion will be absorbed as a whole on some small triggering site, or will not be absorbed at all on that site. The transit distance is estimated to be about 50 nanometers (Fogelson & Zucker, 1985; Schweizer, Betz, & Augustine, 1995), but the total distance traveled is increased many-fold by the diffusion mechanism. Thus the probability cloud becomes spread out over a region that is much larger than the size of the calcium ion itself, or of the trigger site. This converts the classical deterministic model to quantum probabilistic one.

The estimated probability that a vesicle will be released, per incident, input action potential pulse is far less than 100% (maybe only 50%), and if the classical model already gives this number, in terms of the relative frequency of exocytosis per action potential input, there will be a comparable *quantum probability* associated with the spreading of the quantum probability cloud: the two probabilities should be similar in value, though of different theoretical import.

This spreading of the ion wave packet means that the ion may or may not be absorbed on the small triggering site. Accordingly, the contents of the vesicle may or may not be released. Consequently, the quantum state of the nerve terminal becomes a *mixture* consisting of a state where the neurotransmitter is released and a state where the neurotransmitter is not released. This quantum splitting occurs at every one of the trillions of nerve terminals. Thus the quantum uncertainty in what is happening at the nerve terminals propagates via the quantum mechanical Process 2 first to neuronal behaviour, and then to the behaviour of the whole brain, so that, according to quantum theory, the state of the brain becomes a cloudlike collection of an infinitude of classically describable possible brains, each representing a tendency for a corresponding experience to occur.

What is the effect of this replacement of the single, unique, classically described brain of classical physics by a cloud-like quantum brain state composed of a smear of alternative possible classically describable brain states?

A principal function of the brain is to receive clues from the environment, to form an appropriate plan of action, and to direct the activities of the brain and body specified by the selected plan of action. The exact details of the chosen plan will, for a classical model, obviously depend upon the exact values of many noisy and uncontrolled variables. In cases close to a bifurcation point the dynamical effects of noise might tip the balance between two very different responses to the given clues: e.g., tip the balance between the 'fight' or 'flight' response to some shadowy form.

The effect of the simultaneous presence, in the quantum state of the brain, of both the "release" and "don't release" options for each vesicle, coupled with the uncertainty in the timing of the release of the vesicles at each of the trillions of nerve terminals will be to tend to cause the quantum mechanical state of the brain to become mass of different macro-states representing different alternative possible plans of action. Thus the effect of quantum theory is to tend to convert the single unique plan of action that a classical model would be expected to generate into a representation of the agent's brain that encompasses a whole continuous smear of possible actions, each with a weighting associated with the likelihood of that action in that circumstance.

This property of a quantum brain, to tend to produce more than a single plan of action, can be expected to be curtailed by the parallel-processing structure of the brain. Thus in "cut-and-dried" situations, in which there is only one optimal response to the situation in which the person finds himself, one can reasonably expect an essentially deterministic response to occur. But in situations requiring delicate evaluations of moral sentiments and practical consequences, with a feeling of wavering and uncertainty, and of a plumbing of one's depths, it is not unreasonable to expect that the massive uncertainty introduced at the micro-level will eventuate in *some* uncertainty of the macroscopic response. The magnitude of this macro-uncertainty will depend upon fine details of the structure of the brain that are still unknown, and that may remain so for a long time. But in a brain that has evolved to take advantage of the possibilities offered by the more holistic quantum dynamics it would be natural for the structure of the brain to be such that the more sophisticated features of orthodox quantum dynamics can enter. The primacy of quantum mechanics thus *opens the door* to the possibility that a classical understanding of the activities of the brain is inferior in practice to a quantum understanding, in which the inputs of our conscious choices via Process 1 are treated as empirically observed or consciously controlled inputs, which, due to the inherent underlying microscopic quantum uncertainties, are simply not fully determined by local deterministic processes.

As long as the brain dynamics is controlled wholly by Process 2---which is the quantum generalization of the process governed by the Newtonian laws of motion of classical physics---all of the various alternative possible plans of action, however many they may be, will exist in parallel. Insofar as there is macroscopic uncertainty no one plan of action is singled out as the one that will actually occur. Some other process, beyond the local deterministic Process 2, is required to tie the cloud of alternative conflicting possibilities to the person's experienced stream of conscious thoughts.

According to orthodox (von Neumann) quantum theory, that other process is Process 1, which picks out one probing action from the host of possibilities. This selection process is not determined by the mechanical Process 2 that is the quantum replacement of the deterministic laws of motion. Process 1 enters into orthodox quantum theory as a consequence of a "free choice" on the part of the human agent. It is not fixed by any known law. Thus the change from classical physics to quantum physics can radically alter the role of our conscious thoughts. According to classical physics our conscious thoughts are mere passive witnesses to what the atoms are already doing on their own, or perhaps some sort of---causally superfluous---re-expression or re-presentation of what those atoms are already doing on their own. But according to orthodox von Neumann quantum theory our conscious choices are, in general, not causally superfluous. They are needed elements in the dynamics of a conscious brain that, however, *are not determined by any known law*, but are *treated,* in applications, as the immediate cause of the Process 1 action.

In summary, the inadequacy-in-principle of classical mechanics for the treatment of brain dynamics stems from the quantum uncertainties in the location of the individual calcium ions in nerve terminals (along with many other microscopic quantum uncertainties in the brain that increase even further this lack of determinateness.) These uncertainties at the micro-level propagate by the local deterministic Process 2 into uncertainties in the *macroscopic* state of the brain. If no reverse process intervenes, and effectively eliminates this smearing-out effect, then the macroscopic brain would, become essentially a smeared out collection of classical possibilities.

To reduce such smears of macroscopic possibilities to brain states concordant with the empirical realities of our conscious experiences orthodox quantum theory introduces the interventions of causally efficacious Process 1 choices. These choices are not specified by the quantum mechanical counterpart on the mechanical laws of classical physics, namely Process 2, but are treated, in actual scientific practice, as being immediately caused by conscious intent itself, with the causal roots of our conscious choices not yet pinned down by basic science.

5. Templates for Action

Physical systems can be described in many alternative possible ways. The variables that describe the individual particles of a large system can be combined in ways that produce new "macroscopic" variables that are more suited to the description of the observed features of the large system.

When I considered earlier the question of whether quantum effects are important in principle in brain dynamics I focused on the individual calcium ions entering nerve terminals. But Process 1 is associated with conscious experiences, and hence (I shall assume) with collective motions of many particles of the brain, and hence with variables that are naturally connected to these collective motions.

The aspect of the brain state that corresponds to the intention to produce some specified experiential feedback is expected (by me at least) to be a highly organized large-scale pattern of brain activity that, to be effective, must endure for a period of perhaps tens or hundreds of milli-seconds. It must endure for an extended period in order to be able to direct the course of brain activities in a way concomitant with the intention. Thus the neural (or brain) correlate of the intentional act should be something like a collection of the vibratory modes of a drumhead in which many particles move in a coordinated way for an extended period of time.

In quantum theory the enduring states are vibratory states. They are like the lowest-energy state of the simple harmonic oscillator discussed above, which tends to endure for a long time, or like the states obtained from such lowest-energy states by spatial displacements and shifts in velocity. Such states tend to endure as oscillating states, rather than quickly dissolving into chaotic disorder.

I shall call by the name "Template for Action" a macroscopic oscillatory brain state that will, if held in place for an extended period, tend to produce some particular action. Trial and error learning, extended over the evolutionary development of the species and over the life of the individual agent, should have the effect of bringing prominently into the agent's repertoire of Process 1 actions those in which the physical brain counterpart of the psychologically felt intent tends to actualize a template for action that will, if held in place for an extended period, tend to generate the intended recognizable “Yes” feedback corresponding to the successful realization of the intention.

This understanding of the causal role of the agent’s conscious choices arises naturally, and essentially automatically, from von Neumann’s formulation of quantum theory. It ties psychologically described intentions to their functional brain correlates via a key dynamical element of the contemporary physical theory, von Neumann’s Process 1.

It is essential to the rational coherence of this understanding that the conscious choices be physically efficacious. Choices that are causally inert would lack the capacity to become linked to functionally appropriate physical effects by the natural processes of evolutionary selection and trial and error learning.

6. The Physical Effectiveness of Conscious Will

A crucial question now arises: How does this dynamical psycho-neurological connection via Process 1, *which can merely pose a question*, allow a person’s conscious choices to exercise effective control over his or her physical actions?

A Process 1 action appears *in the mathematics* as a posing of a question. But it may appear *in the consciousness of the agent* as an intention to achieve some intended feedback. Let the question posed by the agent be one with just two possible answers ‘Yes’ and ‘No’, where ‘Yes’ is the desired feedback and ‘No’ is the failure of the ‘Yes’ feedback to occur. But whether or not the ‘Yes’ feedback appears is determined by “nature” on the basis of a statistical law. So the effectiveness of our conscious choices would seem to be quite limited. The control exercised by our “freely chosen” conscious choices would tend to be *diluted, and perhaps even nullified,* by the presence of quantum randomness in nature’s choice of the feedback.

A well-known feature of quantum theory provides a way out.

The Quantum Zeno Effect.

A frequently discussed feature of the dynamical rules of quantum theory is this: Suppose a Process 1 query that leads to a ‘Yes’ outcome is followed by a rapid sequence of very similar Process 1 queries. That is, suppose a sequence of similar intentional acts is performed, that the first outcome is ‘Yes’, and that the actions in this sequence occur in very rapid succession on the time scale of the evolution of the original ‘Yes’ state. Then the dynamical rules of quantum theory entail that the sequence of outcomes will, with high probability, all be ‘Yes’: the original ‘Yes’ state will, with high probability, be held approximately in place by the rapid succession of intentional acts, even in the face of very strong physical forces that would, in the absence of this rapid sequence of intentional acts, quickly cause the state to evolve into some very different state..

The *timings* of the Process 1 actions are, within the orthodox formulations, controlled by the “free choices” on the part of the agent. So it is consistent and reasonable to add to the von Neumann rules the assumption that the rapidity of a succession of essentially identical Process 1 actions can be increased by mental effort. Then we obtain, as a mathematical consequence of the basic dynamical laws of quantum mechanics described by von Neumann, a potentially powerful effect of mental effort on the physical world!

This “holding-in-place” effect is called the Quantum Zeno Effect. That appellation was picked by the physicists E.C.G. Sudarshan and R. Misra, to note a (very rough) similarity of this effect to a paradox discussed by the fifth century B.C. Greek philosopher, Zeno the Eleatic. Another name for this effect is “the watched-pot effect”.

Zeno’s paradox is no real problem or paradox, but the quantum Zeno “holding” effect is a rigorous consequence of the basic laws of quantum mechanics. In the present context the intentional act is associated with a macroscopic pattern of brain/body activity identified as a “Template for Action”. This particular pattern of neural/brain activity is actualized by the ‘Yes’ response to the Process 1 probing action. The succession of similar probing actions must occur rapidly on the scale of the natural changes in the “Yes” state in order for the quantum Zeno effect to come into play, and hold this Template of Action in place for a long time, relative to it natural rate of change.

The “Quantum Zeno Effect” can, in principle, hold an intention and its template in place in the face of strong mechanical forces that would tend to disturb it. This means that agents whose mental efforts can increase the rapidity of Process 1 actions would enjoy a survival advantage over competitors that lack such features. They could sustain beneficial templates for action in place longer than competitors who lack this capacity. Thus the dynamical rules of quantum mechanics *allow* conscious effort to be endowed with the causal efficacy needed to permit its evolution and deployment via natural selection and learning.

Mind and Brain

A person’s experiential life is a stream of conscious experiences. The person’s *experienced* ‘self’ is part of this stream of consciousness: it is not an extra thing that stands outside or apart from that stream. In the words of William James “thought is itself the thinker, and psychology need not look beyond.” The “experienced self” is a slowly changing “fringe” part of the stream of consciousness. It is the experiential context for the central focus of attention.

The physical brain, evolving mechanically in accordance with the local deterministic Process 2, does most of the necessary work of the mind-brain, without the intervention of Process 1. It does its job of creating, on the basis of its interpretation of the clues provided by the senses, a suitable response. But, due to the way it operates, Process 2 necessarily generates, in a continuously evolving way, an amorphous mass of overlapping and conflicting templates for action. A Process 1 action, if it occurs, extracts from this jumbled mass of possibilities some particular intentional action directed at some intended feedback. If the ‘Yes’ feedback occurs and includes a positive evaluative component that triggers a quick re-posing of the query then the quantum Zeno effect can convert this positive evaluation into positive action. Such a use by nature of the quantum Zeno effect would promote the survival of any species that can exploit it. The causal efficacy of our conscious thoughts can thereby arise in a natural and naturalistic way, within the framework provided by the known laws of contemporary orthodox quantum theory.

But does this quantum-physics-based theory of the causal dynamical connection between mind and brain explain anything?

William James’s Theory of Volition

This theory was already in place when a colleague, Dr. Jeffrey Schwartz, brought to my attention some passages from ``Psychology: The Briefer Course'', written by William James. In the final section of the chapter on Attention James (1892) writes:

> I have spoken as if our attention were wholly determined by neural conditions. I believe that the array of things we can attend to is so determined. No object can catch our attention except by the neural machinery. But the amount of the attention which an object receives after it has caught our attention is another question. It often takes effort to keep mind upon it. We feel that we can make more or less of the effort as we choose. If this feeling be not deceptive, if our effort be a spiritual force, and an indeterminate one, then of course it contributes coequally with the cerebral conditions to the result. Though it introduce no new idea, it will deepen and prolong the stay in consciousness of innumerable ideas which else would fade more quickly away. The delay thus gained might not be more than a second in duration---but that second may be critical; for in the rising and falling considerations in the mind, where two associated systems of them are nearly in equilibrium it is often a matter of but a second more or less of attention at the outset, whether one system shall gain force to occupy the field and develop itself and exclude the other, or be excluded itself by the other. When developed it may make us act, and that act may seal our doom. When we come to the chapter on the Will we shall see

> that the whole drama of the voluntary life hinges on the attention, slightly more or slightly less, which rival motor ideas may receive. ...

In the chapter on Will, in the section entitled “Volitional effort is effort of attention” James writes:

> Thus we find that we reach the heart of our inquiry into volition when we ask by what process is it that the thought of any given action comes to prevail stably in the mind.

and later

> The essential achievement of the will, in short, when it is most `voluntary,' is to attend to a difficult object and hold it fast before the mind. ... Effort of attention is thus the essential phenomenon of will.

Still later, James says:

> Consent to the idea's undivided presence, this is effort's sole achievement.”...“Everywhere, then, the function of effort is the same: to keep affirming and adopting the thought which, if left to itself, would slip away.

James apparently recognized the incompatibility of these pronouncements with the physics of his day. At the end of “Psychology: The Briefer Course” he said, presciently, of the scientists who would one day illuminate the mind-body problem:

> the best way in which we can facilitate their advent is to understand how great is the darkness in which we grope, and never forget that the natural-science assumptions with which we started are provisional and revisable things.

It is a testimony to the power of the grip of old ideas on the minds of scientists and philosophers alike that what was apparently evident to William James already in 1892---namely that a revision of the mechanical precepts of nineteenth century physics would be needed to accommodate the structural features of our conscious experiences---still fails to be recognized by many of the affected professionals even today, more than three-quarters of a century after the downfall of classical physics, apparently foreseen by James, has come, much-heralded, to pass.

James’s description of the effect of volition on the course of mind-brain process is remarkably in line with what had been proposed, independently, from purely theoretical considerations of the quantum physics of this process. The connections described by James are explained on the basis of the same dynamical principles that had been introduced by physicists to explain atomic phenomena. Thus the whole range of science, from atomic physics to mind-brain dynamics, is brought together in a single rationally coherent theory of a world that is constituted not of matter, as classically conceived, but of the two elements that combine to constitute actual scientific practice---namely the psychologically described and the physically described features---connected in the way specified by contemporary orthodox physical theory.

No comparable success has been achieved within the framework of classical physics, in spite of intense efforts spanning more than three centuries. The reasons for this failure are easy to see: classical physics systematically exorcizes all traces of mind from its precepts, and thereby banishes any logical foothold for recovering mind. Moreover, according to quantum physics all causal effects of consciousness act within the latitude provided by the uncertainty principle, and this latitude shrinks to zero in the classical approximation. Hence the causal effects of consciousness are squeezed to nothing in the classical approximation.

7. Support from Contemporary Psychology

A great deal has happened in psychology since the time of William James. However, scientific theoretical work in the field has been severely restricted by the adherence of most science-oriented psychologists, neuroscientists, and philosophers of mind to what they perceived to be the verdict of physics, namely the principle of the causal closure of the physical. This doctrine---that the course of physical events, including all human behaviour, is determined by “physical” causes alone---led researchers to reject as unscientific, or incompatible with the principles of science, the possibility that our conscious choices enter into brain dynamics as bona fide causal elements, not replaceable by, or reducible to, effects describable in terms of physical variables. The psychologists, neuroscientists, and philosophers followed (blindly) the lead of the eighteenth and nineteenth century physicists by taking physical causation to be universally sufficient, but then failed to stay in step when the founders of quantum mechanics jettisoned that principle. While the physicists were bringing in conscious agents armed with “free choices”, and Process 1 interventions into the Process 2 generalizations of the failed deterministic laws of classical physics, the psychologists were turning to “behaviourism”, which sought to abolish in the study of mind the use not only of introspective data but also the very concept of consciousness.

The eventual failure of the behaviourist program to account for the facts of human behaviour, and in particular for linguistic behaviour, led to the rehabilitation of “attention'' during the fifties, and many hundreds of experiments have been performed during the past fifty years for the purpose of investigating empirically those aspects of human behaviour that we ordinarily link to our consciousness. How well does the above-described quantum-theory-based approach to mind-brain dynamics account for this newer data?

Harold Pashler's 1998 book *The Psychology of Attention* describes a great deal of this empirical work, as well as the intertwined theoretical efforts to understand the nature of an information-processing system that could account for the fine details of the empirical data. Two key concepts are the notions of “Attention” and of a processing “Capacity”. The former is associated with an internally directed selection between different possible allocations of the available processing “Capacity”. A third concept is “Effort”, which is empirically linked to incentives, and to reports by subjects of “trying harder”. Effort increases the portion of the processing capacity that is being applied to a cognitively directed task.

Pashler organizes his discussion by separating perceptual processing from post-perceptual processing. The former covers processing that, first of all, identifies such basic physical properties of stimuli as location, color, loudness, and pitch, and, secondly, identifies stimuli in terms of categories of meaning. The post-perceptual process covers the tasks of producing motor actions and cognitive action beyond mere categorical identification. Pashler emphasizes [p. 33] that “the empirical findings of attention studies specifically argue for a distinction between perceptual limitations and more central limitations involved in thought and the planning of action.” The existence of these two different processes, with different characteristics, is a principal theme of Pashler's book [p. 33, 263, 293, 317, 404]

Orthodox quantum theory also features two separate processes. Quantum theory, applied to the mind-brain system, in accordance with von Neumann’s formulation, involves, first, the unconscious mechanical brain process called Process 2. A huge industry has developed that traces these essentially classically describable processes in the brain. But, according to orthodox contemporary physics, another process, von Neumann's Process 1, must also enter into the causal structure. Its physical effects can become manifest in connection with an impulsive feeling described as “effort”. The effect of this “effort of attention” is to inject into brain activity, and thence eventually into overt behaviour, effects of *intentional inputs.*

Two kinds of Process 1 actions are possible. One kind would be determined by brain activity alone. It would be the kind of action associated with James’s assertion that “No object can catch our attention except by the neural machinery.” However, another kind of Process 1 action is possible within the framework provided by von Neumann’s formulation. It can stem from a *positive evaluation* based on the felt or experiential quality of internal coherence, and would tend to make the Process 1 psychophysical event in which it occurs immediately repeat itself a short time later, with the rapidity of these repeated actions being increasable, *up to a certain limit*, by an experienced quality of the event called “effort”. Such a Process 1 action could, within the orthodox quantum framework, induce a rapid sequence of similar actions that could activate a quantum Zeno effect that would effectively inject a rapid sequence of mental intentions into the course of brain activity.

This quantum conceptualization of the action of mind on brain is, as we shall now see, in good accord with the *details* of the data described by Pashler. That data did not necessarily---*from non-quantum considerations*---need to have the detailed structure that it is empirically found to have. Indeed, the various classical-type theories examined by Pashler did not entail it. Consequently this data provides some empirical support for this quantum-physics-based idea of the mind-brain connection

The “perceptual” aspect of brain process discussed by Pashler can be associated with Process 2, and also with the essentially passive Process 1, whereas the higher-level processing that Pashler identifies can be associated with the active mode of Process 1.

The *perceptual* aspects of the data described by Pashler can, I believe, be accounted for by essentially classical parallel mechanical processing. But it is the high-level processing, which is linked to active mental effort, that is of prime interest here. The data pertaining to this second kind of process is the focus of Part II of Pashler's book.

Examination of Part II of Pashler's book shows that the quantum-physics-based theory accommodates naturally all of the detailed structural features of the empirical data that he describes. He emphasizes [p. 33] a specific finding, namely strong empirical evidence for what he calls a *central processing bottleneck* associated with the attentive selection of a motor action. This kind of bottleneck is what the quantum-physics-based theory predicts: the bottleneck is precisely the single linear sequence of Process 1 actions that enters so importantly into the quantum theoretic description of the mind-matter connection.

The sort of effect that Pashler finds is illustrated by a result he describes that dates from the nineteenth century: mental exertion reduces the amount of physical force that a person can apply. He notes that “This puzzling phenomena remains unexplained.” [p. 387]. However, it is a natural consequence of the physics-based theory: creating physical force by muscle contraction requires an effort that opposes the natural dissipative physical tendencies generated by Process 2. This opposing tendency is produced by the quantum Zeno effect, and should be roughly proportional to the number of bits per second of central processing capacity that is devoted to the task. So if part of this processing capacity is directed to another task, then the muscular force will diminish.

An interesting experiment mentioned by Pashler involves the simultaneous tasks of doing an IQ test and giving a foot response to rapidly presented sequences of tones of either 2000 or 250 Hz. The subject's mental age, as measured by the IQ test, was reduced from adult to 8 years. Effort can be divided, but at a maximal level there is a net total rate of effortful Process 1 action..

Another interesting experiment showed that, when performing at maximum speed, with fixed accuracy, subjects produced responses at the same rate whether performing one task or two simultaneously: the limited capacity to produce responses can be divided between two simultaneously performed tasks. [p. 301]

Pashler also notes [p. 348] that ``Recent results strengthen the case for central interference even further, concluding that *memory retrieval* is subject to the same discrete processing bottleneck that prevents simultaneous response selection in two speeded choice tasks."

In the section on ``Mental Effort" Pashler reports that ``incentives to perform especially well lead subjects to improve both speed and accuracy", and that the motivation had ``greater effects on the more cognitively complex activity". This is what would be expected if incentives lead to effort that produces increased rapidity of the events, each of which injects mental intent into the physical process.

Studies of sleep-deprived subjects suggest that in these cases ``effort works to counteract low arousal". If arousal is essentially the rate of occurrence of conscious events then this result is what the quantum model would predict.

Pashler notes that ``Performing two tasks at the same time, for example, almost invariably... produces poorer performance in a task and increases ratings in effortfulness." And ``Increasing the rate at which events occur in experimenter-paced tasks often increases effort ratings without affecting performance". ``Increasing incentives often raises workload ratings and performance at the same time." All of these empirical connections are in line with the general principle that effort increases the rate of conscious events, each of which inputs a mental intention, and that this resource can be divided between tasks.

After analyzing various possible mechanisms that could cause the central bottleneck, Pashler [p.307-8] says ``the question of why this should be the case is quite puzzling."

The citing of this data is meant only to indicate that this data *is in natural concordance* with the structure of orthodox (von Neumann) quantum mechanics, supplemented by the idea that mental effort can, *by virtue of the known quantum laws*, tend to hold in place attention, and thus tend to instigate consciously intended physical actions. Citing this data is *not* intended to show that von Neumann quantum mechanics is the *only* possible way to explain these empirical findings. Still, orthodox von Neumann quantum does provide the foundation for a natural physics-based causal explanation of this complex data that is in line with our normal intuition that our conscious efforts can influence our physical actions. Adopting orthodox von Neumann quantum theory allows one to avoid the gross philosophical contortions that have been proposed in order to reconcile the apparent physical efficacy of conscious effort with the theories of that enforce the causal closure of the physical description.

8. Application to neuropsychology.

The most direct evidence pertaining to the effects of conscious choices upon brain activities comes from experiments in which consciously controlled cognitive efforts are found to be empirically correlated to measured physical effects in the brain. An example is the experiment of Ochsner et.al. (2001). The subjects are trained how to cognitively re-evaluate emotional scenes by consciously creating and holding in place an alternative fictional story of what is really happening in connection with an emotion-generating scene they are viewing.

> The trial began with a 4 sec presentation of a negative or neutral photo, during which participants were instructed simply to view the stimulus on the screen. This interval was intended to provide time for participants to apprehend complex scenes and allow an emotional response to be generated that participants would then be asked to regulate. The word Attend (for negative or neutral photos) or Reappraise (negative photos only) then appeared beneath the photo and the participants followed this instruction for 4 sec …
> To verify whether the participants had, in fact, reappraised in this manner, during the post-scan rating session participants were asked to indicate for each photo whether they had reinterpreted the photo (as instructed) or had used some other type of reappraisal strategy. Compliance was high: On less than 4% of trials with highly negative photos did participants report using another type of strategy.

Reports such as these can be taken as evidence that the streams of consciousness of the participants do exist and contain elements identifiable as efforts to reappraise.

Patterns of brain activity accompanying reappraisal efforts were assessed by using functional magnetic imaging resonance (fMRI). The fMRI results were that reappraisal was positively correlated with increased activity in the left lateral prefrontal cortex and the dorsal medial prefrontal cortex (regions thought to be connected to cognitive control) and decreased activity in the (emotion-related) amygdala and medial orbito-frontal cortex.

How can we explain the correlation revealed in this experiment between the mental reality of “conscious effort” and the physical reality of measured brain behaviour?

The classical approach is based on the idea that every physical effect is traceable in principle to exclusively physically describable causes. But according to contemporary physics, the physically described properties of the cloudlike state of the brain can be insufficiently well defined to determine either the subsequent choice itself, or the physical consequences of that choice! This means that classical explanations that disregard the quantum uncertainties are based on an improper idealization that lies *in principle* beyond the limits of empirical verification---in situations such as this where the behaviour of the brain can depend sensitively on the motions of ions in nerve terminals. But in such situations the structure of quantum theory allows what is *unknowable in principle*, namely the empirically inaccessible physical features, to be replaced by a different kind of data that *is* knowable in principle, namely our conscious choices of how we will act. Within the framework provided by the laws of quantum mechanics this replacement of inaccessible data by accessible data leads to statistical predictions connecting empirically described intentional inputs to empirically described perceptual feedbacks. The empirical and theoretical components of scientific practice become glued together by the quantum laws.

There are important similarities and also important differences between the classical and quantum treatments of the experiments of Ochsner et al. (2002). In both approaches the atomic constituents of the brain can be conceived to be collected into nerves and other biological structures, and into fluxes of ions and electrons, which can all be described reasonably well in essentially classical terms. But in the classical approach the physical changes must in principle be deterministically described in terms of physical variables alone, with no acknowledgement of the existence of the conscious efforts upon which they seem to depend. By contrast, in the quantum approach the various empirically described inputs and outputs are causally connected together by the basic laws of orthodox contemporary physics, *without referring to the causes of our conscious choices*. These choices can therefore be rationally treated as free input variables, in absolute accord with empirical practice.

The quantum laws, in the von Neumann formulation, refer to psychophysical events that can monitor and guide the physical process in the brain. When no mental effort is applied, the temporal development of the body/brain should be roughly in accord with the principles of classical statistical mechanics---due to the disruption of quantum effects by thermal noise and interactions with the environment. But, according to the quantum laws, important departures from the classical statistical predictions can be produced by a conscious effort that increases the rapidity of the monitoring events. Such an increase can cause to be held in place, for an extended period, a pattern of neural activity that constitutes a template for action. The holding-in-place of this template will tend to cause the action specified by that template to occur. Thus the main net effect of the switch to quantum physics, in this realm of phenomena, is simply that consciously controllable mental effort, *without regard to its causal origin*, can inject conscious intention into brain activity. The data is concordant with the presumption that this theoretical possibility is in fact realized in the world of human experience.

In the quantum treatment of the Ochsner experiments the effort of the subject to “reappraise” *causes* the “reappraise” template for action to be held in place, and the holding in place of this template that corresponds to the intention to direct the activities of the brain in this other direction *causes* the suppression of the limbic response. These causal effects are, by virtue of the quantum Zeno effect, direct mathematical consequences of the quantum laws. Thus the “subjective” and “objective” aspects of the data are tied together by quantum rules that directly specify the causal effects of the subject’s conscious choices upon the subject’s physically described brain, *without any need to specify the neural antecedents of these choices.* The form of the quantum laws thus accommodates a natural theoretical breakpoint between the *cause* of willful actions, which are not specified by contemporary physical theory, and their *effects*, which *are* specified by the theory. Consequently, our conscious choices can consistently be treated as empirically specified consciously controlled input variables, just as they are in the realm of atomic physics.

This causal explanation falls apart if one uses the classical approximation. But what is the rational motivation for insisting on the use this approximation? The applicability of the classical approximation to this phenomenon certainly does not follow from physics considerations: calculations based on the known properties of nerve terminals indicate that quantum theory must in principle be used. Nor does it follow from the fact that classical physics works reasonably well in neuroanatomy and neurophysiology: quantum theory explains why the classical approximation works well in those domains. Nor does it follow rationally from the massive analyses and conflicting arguments put forth by philosophers of mind. In view of the turmoil that has engulfed philosophy during the three centuries since Newton cut the bond between mind and matter, the re-bonding achieved by physicists during the first half of the twentieth century must be seen as a momentous development, a lifting of the veil. Ignoring this huge and enormously pertinent development in basic science, and proclaiming the validity of materialism on the basis of inapplicable-in-this-context nineteenth century science is an irrational act.

From the classical materialist point of view the Ochsner experiment is essentially a conditioning protocol, where, however, the “conditioning” is achieved via linguistic communications pertaining to cognitive concepts. But how do the *cognitive realities* of “knowing”, “understanding”, and “feeling” arise out of motions of the miniature planet-like objects of classical physics, which have no trace of any experiential quality? And how do the vibrations that carry the instructions get converted into feelings of understanding? And how do these feelings of understanding get converted to conscious effort, the presence or absence of which determines whether the limbic or frontal regions of the brain will be activated?

The materialist claim is that *someday* these connections will be understood. Karl Popper called this prophecy “promissory materialism”. But can these connections reasonably be expected to be understood in terms of a physical theory that is known to be false, and, moreover, to be false because it is an approximation that eliminates the object of study, namely the causal connection between psychologically and physically described aspects of the mind-brain system?

The only objections I know to applying the basic principles of physics to brain dynamics are, first, the forcefully expressed opinions of some non-physicists that the classical approximation provides an entirely adequate foundation for understanding mind-brain dynamics, in spite of the quantum calculations that indicate the opposite; and second, the opinions of some physicists, who back non-orthodox versions of quantum theory, that the hugely successful orthodox quantum theory, which is intrinsically dualistic, should, for philosophical reasons, be replaced by a theory that re-converts human consciousness into a causally inert witness to the mindless dance of atoms. Neither of these opinions has any secure basis in science.

9. Recent views in Neuroscience and Philosophy.

A tremendous burgeoning of interest in the problem of consciousness is now in progress. The grip of the behaviourists who sought to banish consciousness from science has finally been broken. This shift was ratified, for example, by the appearance of a special issue of Scientific American entitled *The Hidden Mind*. (August 2002).

The lead article, written by Antonio Damasio, begins with the assertion: “At the start of the new millennium, it is apparent that one question towers above all others in the life sciences: How does the set of processes we call mind emerge from the activity of the organ we call brain?” He notes that some thinkers “believe the question to be unanswerable in principle’’ while “For others, the relentless and exponential increase in knowledge may give rise to the vertiginous feeling that no problem can resist the assault of science *if only the science is right* and the techniques are powerful enough.” (My emphasis) He notes that “The naysayers argue that exhaustive compilation of all these data (of neuroscience) adds up to correlates of mental states but to nothing resembling *an actual mental state*.” (His emphasis) He adds that: “In fact, the explanation of the physics related to biological events is still incomplete” and states that “the finest level of description of mind … might require explanation at the quantum level.” Damasio makes his own position clear: “I contend that the biological processes now presumed to correspond to mind in fact are mind processes and will be seen to be so when understood in sufficient detail.”

Whether “biological process…understood in sufficient detail” allows for a quantum understanding is not made clear.

The possibility that quantum physics might be relevant to the connection between conscious process and brain process was raised also by Dave Chalmers, in his contribution “The Puzzle of Conscious Experience” to *The Hidden Mind*. However, Chalmers effectively tied that possibility to a proposal put forth by Roger Penrose (1989, 1994) and, faulting that particular approach, rejected the general idea.

The deficiency of Penrose’s approach identified by Chalmers is that it fails to bring in consciousness: it is about certain brain processes that may be related to consciousness, but “…the theory is silent about how these processes might give rise to conscious experience. Indeed, the same problem arises with any theory of consciousness based only on physical processing.”

Penrose's treatment does indeed focus on physical processing. But quantum theory itself is intrinsically psychophysical: it is a theory about the structure of human experience that is erected upon a mathematical generalization of the laws of classical physics.

Chalmers goes on to expound upon the "explanatory gap" between, on the one hand, theoretical understanding of the behavioural and functional aspects of brain processes and, on the other hand, an explanation of how and why the performance of those functions should be accompanied by conscious experience. Such a gap arises in the classical approximation, but not in orthodox quantum theory, which is fundamentally a causal weaving together of psychologically and physically described realities.

The conflating of Nature herself with the impoverished mechanical conception of it adopted by scientists during the seventeenth century has derailed the philosophies of science and of mind for more than three centuries, by effectively eliminating the causal link between the psychological and physical aspects of nature.

This now-falsified classical conception of the world still exerts a blinding effect. For example, Daniel Dennett (1994: 237) says that his own thinking rests on the idea that "a brain was always going to do what it was caused to do by current, local, mechanical circumstances." But by making that judgment he tied his thinking to the physical half of Cartesian dualism, or its child, classical physics, and thus was forced in his book "Consciousness Explained" (Dennett, 1991) to leave consciousness out, as he himself admits, but tries to justify, at the end of the book. By restricting himself to the classical approximation, which squeezes the effects of consciousness out of the dynamics, Dennett cuts himself off from any possibility of validly explaining the physical efficacy of our conscious efforts.

Francis Crick and Christof Koch begin their essay in *The Hidden Mind* entitled "The Problem of Consciousness" with the assertion: "The overwhelming question in neurobiology today is the relationship between the mind and the brain." But after a brief survey of the difficulties in getting an answer they conclude that: "Radically new concepts may indeed be needed---recall the modifications in scientific thinking forced on us by quantum mechanics. The only sensible approach is to press the experimental attack until we are confronted with dilemmas that call for new ways of thinking."

However, the two cases compared by Crick and Koch are extremely dissimilar. The switch to quantum theory was forced upon us by the fact that we had a very simple system---consisting of a single hydrogen atom interacting with the electromagnetic field---that was so simple that it could be exactly solved by the methods of classical physics, but the calculated answer did not agree with the empirical results. There was initially no conceptual problem. It was rather that precise computations were possible, but gave wrong answers. Here the problem is reversed: precise calculations of the dynamical brain processes associated with conscious experiences are not yet possible, and hence have not revealed any mismatch between theory and experiment. The problem is, rather, a conceptual one: the concepts of classical physics that many neurobiologists are committed to using are logically inadequate because, unlike the concepts of quantum physics, they effectively exclude key protagonists, our conscious thoughts.

Dave Chalmers emphasizes this conceptual difficulty, and concludes that experimental work by neurobiologists is not by itself sufficient to resolve "The Puzzle of Conscious Experience". Better concepts are also needed. He suggests that the stuff of the universe might be information, but then, oddly, rejects the replacement of classical physical theory, which is based on material substance, by quantum theory, which is built on the information contained in experienced increments of knowledge.

10. Roger Penrose's Theory and Quantum Decoherence.

Increased interest in quantum mechanical theories of mind has been kindled by two recent books by Roger Penrose. These books, *The Emperor's New Mind*, and *Shadows of the Mind*, along with a paper by Hameroff and Penrose (1996), propose a quantum theory of consciousness that, like the present one, is based on von Neumann's formulation of quantum theory. But the Penrose-Hameroff theory brings in some controversial ideas that are not used, or needed, in the more direct application of orthodox quantum mechanics described in this book.

An essential difference between the present proposal and that of Penrose and Hameroff is that their theory depends on the assumption that a property called "quantum coherence" extends over a large portion of the brain, whereas the theory described here does not. This property is a technical matter that I do not want to enter into here, beyond remarking that most quantum physicists deem it highly unlikely that the quantum coherence required by the Penrose-Hameroff theory could be sustained in a warm, wet, living brain. Quantitative estimates that appear to back up this negative opinion have been made by Tegmark (2000). A rebuttal has been offered by Hagen, Hameroff, and Tuszynski (2002), but the needed level of coherence still looks very difficult to achieve.

The expected (by most physicists) lack of long-range quantum coherence in a living brain is, in fact, a great asset to the von Neumann approach described in this book. This lack of coherence (decoherence) means that the quantum brain can be conceived to be, to a very good approximation, simply a collection of classically conceived alternative possible states of the brain. The point here is that the interaction with the environment effectively washes out all observable effects of the possible-in-principle interferences between spatially separated components of the state of the brain: the only quantum effects that survive are those associated with close neighbors. Thus the quantum state of the brain is effectively, to a good approximation, simply a collection of alternative possible classically described brains, which all exist together as “parallel” parts of a single reality. The residual quantum effects arise from the fact that these quasi-classical “parallel” brain states are allowed to interact with the *almost identical* brain states in this collection of “possibilities”. That feature makes the quantum model different in principle from a purely classical model: no classical possibility can interact with an *alternative* classical possibility, no matter how similar the two alternative possibilities are.

The only pertinent macroscopic effect of this non-classical feature upon the behaviour of brain of a subject, apart from allowing more technically accurate descriptions of chemical interactions, appears to be the quantum Zeno effect. Thus the absence of long-range coherence allows neuroscientists to have a simple intuitive idea of the quantum state of a brain. The quantum brain can be imagined to be an evolving conglomeration of classically conceived possible brains with the following four properties: 1) The set of possibilities fans out in accordance with the uncertainty principle; 2) At each occurrence of a conscious thought, the conglomeration is reduced to the subset compatible with the increment of knowledge represented by the thought; 3) Chemical interactions are treated quantum mechanically; and 4) The quantum Zeno holding action described above acts to keep templates for action in place longer than classical mechanics would allow.

A second principal difference between the Penrose-Hameroff theory and the one being described here is that the former depends on the complex question of the nature of quantum gravity, which is currently not under good theoretical control, whereas the present approach is based only on the *fundamental principles of orthodox quantum theory*, which, thanks to the efforts of John von Neumann, are under good control. Penrose’s proposal strongly links consciousness to the gravitational interactions of parts of the brain with other parts, whereas the theory being advanced here supposes such gravitational effects to be negligible.

The third difference is that Penrose’s approach involves a very much disputed argument that claims to deduce from (1), the fact that mathematicians construct proofs that they believe to be valid, and (2), some deep mathematical results due to Kurt Gödel, the conclusion that conscious thought must involve a non-mechanical (non-algorithmic) process. Quantum theory certainly *allows* consciousness to be connected to non-mechanical processes, because it gives, in fact, no rules for determining the “free” choices made by the agents. But Penrose uses his Gödel argument to conclude that consciousness *cannot* be determined solely by mechanical (algorithmic) process. The present approach argues for the incompleteness of the mechanistic/deterministic description from known physical features of the brain, such as the structure of nerve terminals and ion channels, in conjunction with the uncertainty principle.

The forth difference is the fact, already emphasized by Chalmers, that Penrose’s theory of consciousness turns out to be about brain dynamics, but is virtually silent about the details of how brain activity is connected to conscious thought. The present work is about precisely that question.

11. Non-Orthodox Versions of Quantum Theory and the Need for Process 1.

I have used the word “orthodox” to denote, collectively, both the Copenhagen interpretation of quantum theory and von Neumann’s formulation and extension of it. The defining characteristic is the occurrence of “Process 1”, which is a separation of the current quantum state into a (countable) set of orthogonal component parts that, on the one hand, is not determined by the quantum generalization of the classical laws of motion (Process 2), or by any other known law or rule, but is *treated,* in practical applications, as being determined by a conscious intent.

Eugene Wigner introduced the term “orthodox” to describe essentially von Neumann’s formulation, but I use the term more broadly to include, at the pragmatic level, the also Copenhagen formulation. But at the ontological level the term identifies von Neumann’s formulation.

The main thrust of this book has been to describe the practical and theoretical virtues of using von Neumann’s orthodox development of the Copenhagen interpretation as the foundation of a theory of the relationships between the psychologically and physically described properties of human beings. That application falls short of providing a complete ontology. The most common objection to von Neumann’s theory, as the basis of a complete ontology, that it is not universally accepted by all quantum physicists. All quantum physicists agree that the Copenhagen interpretation, with its emphasis on the active role of the human observer/experimenter, is what is used in actual practice. But it seems obvious that the anthropocentric focus of the Copenhagen interpretation must be eliminated in order to cope, for example, with the quantum aspects of cosmology. At the birth of the universe no human beings were present, and hence no probing actions were being chosen by human agents. The present approach is to develop applications of the orthodox approach in contemporary psychology and neuroscience, while recognizing the need for an eventual non-anthropocentric extension.

All physicists agree, I believe, that the first step beyond the pragmatic Copenhagen stance is von Neumann’s inclusion of the entire physical universe. But opinions differ on what to do next. The line of attack described in this book is to start by building directly on the orthodox von Neumann structure, which is closely connected to the empirically supported Copenhagen approach. This allows one to exploit the properties of von Neumann’s Process 1 in order to explain the causal effectiveness of our conscious thoughts. But the anthropocentric aspects of the original Copenhagen formulation must be eliminated when one goes to an *ontological* interpretation, in order to account for the evolution of consciousness in accordance with Darwinian ideas.

A key feature of quantum theory is that it is exceedingly difficult to detect by physical measurements whether or not a large physical system that is strongly interacting with its environment is acting as a quantum agent. It is almost impossible to determine, by direct measurements, whether reduction events are actually occurring in such a system. This lacuna at the empirical level is matched by a corresponding openness of von Neumann's theory, arising from the general lack of specificity about Process 4. It is altogether possible that the action of Process 4 should depend strongly upon the specific physical nature of the system associated with the reduction event. Thus the action of the *analog* of human consciousness in a nonhuman agent can presumably depend strongly on the physical character of that nonhuman agent. Correspondingly, the qualitative feel in a very nonhuman agent of the analog of a human conscious intent, or conscious feedback, could be very different from the feel of any human experience.

The scientific exploration of non-human "consciousness" is hampered by the fact that almost nothing is empirically known even about which macro systems act as agents, aside from the human agents that constitute the original basis of the development of quantum theory. Those uncertainties do not affect the main content of the present work, which has been to describe the benefits of applying the von Neumann ontology in a particular domain of phenomena that is currently under intense empirical scrutiny, namely connections between the psychologically and physically described aspects of *conscious human beings*. This realm of phenomena is scientifically important because we have an explosively growing body of pertinent data. So it is reasonable to see how well *the orthodox theory* works in this arena, which is closest to home, so to speak, and for which there is abundant pertinent data. *If* the theory works well there, then a reasonable approach to a general ontology would be to build out from this empirically supported base, retaining thereby the great innovation made by the founders, namely the rational incorporation, via Process 1, of conscious intent into the physically described properties of nature

This conservative approach to ontology, based on empirically supported orthodox quantum theory, with its crucial dependence on Process 1---and conscious intent---is not favored by all physicists. Many prefer to revert to a more classical kind of physical theory that enforces the causal closure of the physical, and thus eliminates both Process 1 and, with it, any role for conscious intent not reducible to essentially physical/mechanical terms.

There are three main non-orthodox approaches to the problem of imbedding pragmatically validated quantum theory in some conception of reality itself. These are the many-worlds approach initiated by Everett (1957), the pilot-wave approach of Bohm (1952, 1993) and the spontaneous-reductions approach of Ghirardi, Rimini, and Weber (1986).

The many-worlds approach maintains that the quantum state of the universe exists and evolves *always* under the exclusive control of the local deterministic Process 2. In this scheme no reduction events occur at the level of objective reality itself: all possible outcomes of all possible observations really do occur, in some absolute or objective sense. The fact that we *seem* to choose a particular experiment that *seems* to have a particular outcome then needs to be explained as essentially some kind of subjective illusion.

The pilot-wave approach claims that there really is a world of the kind specified in classical physics, and *also* a real state of the universe of the kind specified in quantum theory. It asserts that this latter world always evolves via Process 2, but that the real classical world is buffeted around by the real quantum world in a way that accounts for the validity of the predictions of pragmatic quantum theory.

The spontaneous-reductions approach maintains that the evolution via the local mechanical process 2 is interrupted from time to time by a sudden spontaneous (possibly random) reduction event that keeps the physical universe, at the visible level, roughly in accord with the ideas of classical physics.

All three of these approaches differ fundamentally from the von Neumann approach in that they adhere to the principle of the causal closure of the physical, and hence exclude any essential causal role for our conscious thoughts and efforts. However, all three have run into serious technical difficulties.

The Many-Worlds (or Many-Minds) Approach

I received recently a query from a colleague, who wrote:

I would appreciate your answering a question I have.

> There is much disagreement in the literature about the reduction process and how it works, including controversy over whether there is any such thing as reduction. I have read numerous statements from physicists that measurement involves interaction of a quantum system with its environment, and is (it is asserted) therefore "nothing but" Schroedinger evolution on a larger system.

The Schroedinger evolution is another name for Process 2.

It is indeed sometimes claimed that the interaction of a system with its environment effectively solves the “measurement” problem (which is essentially the problem of how connect the mathematical rules of quantum theory to human experience.). However, the principal investigators of the effects of these interactions (e.g., E. Joos, 1996; D. Zeh, 1996; W. Zurek, 2002) make no such strong claim. Joos (p.3) emphasizes that even when the interaction with the environment is included one is left with not one single classical world but with a host of possible classical worlds "thus leaving the measurement problem essentially unsolved (unless one is willing to accept some variant of the Everett interpretation)". Zeh (p.17), commenting on the problems that remain after the interaction with the environment has been included, says "A way out of this dilemma in terms of the wave function itself seems to require one of the following two possibilities: (1) a modification of the Schroedinger equation that explicitly describes a collapse… or (2) an Everett type of solution, in which all measurement outcomes are assumed to coexist in one formal superposition, but to be perceived separately as a consequence of their dynamical decoupling." This "Everett type of solution" is usually called a Many Worlds or a Many Minds solution.

Zurek (p.5) says:

> At first glance, the Many Worlds and Copenhagen Interpretation have little in common. The Copenhagen Interpretation demands an a priori "classical domain" with a border that enforces a classical "embargo" by letting through just one potential outcome. The Many Worlds Interpretation aims to abolish the need for a border altogether. Every potential outcome is accommodated in the ever-proliferating branches of the wave function of the Universe. The similarity between the difficulties faced by these two viewpoints becomes apparent, nevertheless, when we ask the obvious question, "Why do I, the observer, perceive only one of the outcomes?" Quantum theory with its freedom to rotate bases in the Hilbert space, does not even define which states of the Universe correspond to the "branches." Yet our perception of a reality with alternatives---not a coherent superposition of alternatives---demands an explanation of when, where, and how it is decided what the observer actually records. Considered in this context, the Many Worlds Interpretation in its original version does not really abolish the border but pushes it all the way to the boundary between the physical universe and consciousness. Needless to say, this is a very uncomfortable place to do physics.

Later on (p.20-21) he returns to this problem: "why do we perceive just one of the quantum alternatives?" "the process of decoherence we have described above is bound to affect the states of the brain…decohence applies to our own "state of mind." "There is little doubt that the process of decoherence sketched in this paper is an important element of the big picture… There is even less doubt that this rough outline will be further extended. Much work needs to be done, both on technical issues…and on problems that require new conceptual input (such as … answering the question of how an observer fits into the big picture.)"

These comments make clear the fact that interaction with the environment (and the resulting technical effect known as environmental decoherence) does not by itself solve the measurement problem, namely the problem of accounting for the fact that an observer perceives just one classically describable world, not the infinite collection of them generated by Process 2 acting alone---*which includes all effects of the environment.*

The question, then, is whether the Many Worlds/Minds option is rationally acceptable. I have described (in Stapp, 2002) a specific difficulty with the many-worlds approach that is sufficiently serious to block, at the present time, the claim that the Schroedinger equation alone (i.e., Process 2), including all interactions with the environment, is sufficient---without Process 1, or some surrogate of Process 1---to tie the quantum mathematics to testable predictions about human experiences. Such predictions are required for the theory to be scientifically meaningful, and they are obtained in the Copenhagen/von Neumann orthodox approach only by bringing in Process 1 interventions.

The reason, in brief, why Process 1, or something that does the same job, seems to be needed is this: If the universe has been evolving since the big bang solely under the influence of the Schroedinger equation---i.e., Process 2---then every object and every human brain would by now, due to the uncertainty conditions on the original positions and velocities, be represented in quantum theory by an amorphous continuum; the center-point of each object would not lie at a particular point, or even be confined to a small region, but would be continuously spread out over a huge region. Likewise, the state of the brain of every observer of this object would be a smeared out conglomeration of many different classical-type brains. That is, if a human person were observing an object, whose center-point, as specified by its quantum state, were spread out over a region several meters in diameter, then the state of the brain of that person would have, for each of these different locations, a part corresponding to the observer's seeing the object in that location. If each of these parts of the brain were accompanied by the corresponding experience, then there would exist not just one experience corresponding to seeing the object in just one place, but a continuous aggregation of experiences, with one experience for each of the possible locations of the object in the large region. Thus this theory is often called, quite rightly, a "many-minds" interpretation: each person's brain evolves quickly into a smeared out continuum, and each stream of consciousness would be part of a continuous blur of classically describable possibilities.

In order to extract from quantum theory a set of predictions pertaining to human experiences, and hence to give empirical meaning to the theory, this smeared out collection of different brain structures must be resolved in a very special way into a collection of discrete parts, each corresponding to one possible experience. This discreteness condition is a technical point, but it constitutes the essential core of the measurement problem. Hence I must explain it! It is called the measurement problem.

Evolution according to the Schroedinger equation (Process 2) generates in general, as I have just explained, a state of the brain of an observer that is a smeared out continuum of component parts. One cannot assign a nonzero probability to each one of such a continuum of possibilities, because the total probability would then be infinity, instead of one (unity). However, the mathematical rules of quantum theory have a well-defined way to deal with this situation: they demand that the space of possibilities be divided in a certain very restrictive way into a countable set of alternative possibilities, where a “countable” set is a set that can be numbered (i.e., placed in one-to-one correspondence with the whole numbers 1, 2, 3, … or with some finite subset of these numbers.) The need to specify a particular countable set of parts is the essential problem in the construction of a satisfactory quantum theory. But then the technical problem that the Many-Worlders must resolve is this: How does one specify a satisfactory particular countable set of different brain states from Process 2 alone, when Process 2 is a continuous local process that generates a structure that continuously connects components that correspond to very different experiences, and hence must belong to different members of the countable set? The problem is to divide a continuum of brain states into a countable set of discrete (and orthogonal) components by means of the continuous Process 2 alone.

Copenhagen quantum theory accomplishes this selection of a preferred set of discrete states by means of an intervention of the experimenter. In the simplest case the countable set of distinguishable experiences has just two elements, “Yes” and “No”. The experimenter selects a particular probing action that picks out from the continuously infinite set of possible queries some particular one. In this way, the basic problem of specifying a countable set of discrete parts is solved by bringing into the theory choices on the part of the experimenter. Von Neumann solves this discreteness problem in this same way, and gives this crucial agent-dependent selection process the name “Process 1”.

Einstein (1951, p. 670) posed essentially the same problem in a clear way. Suppose a pen that draws a line on a moving scroll is caused to draw a blip when a radioactive decay is detected by some detector. If the only process in nature is Process 2, then the state of the scroll will be a blurred out state in which the blip occurs in a continuum of alternative possible locations. Correspondingly, the brain of a person who is observing the scroll will be in a smeared out state containing a continuously connected collection of components, with one component corresponding to each of the possible locations of the blip on the scroll. But how does this smeared out continuously connected state of the brain get divided by Process 2 alone into components to which well-defined probabilities can be assigned? The quantum statistical predictions cover only those cases in which there is a specified countable collection of distinct possibilities.

A key feature of the orthodox approach is the “empirical fact” that experimenters do have definite thoughts, and that they can therefore place the devices in definite locations. Thus it is the discreteness of the choice made by the experimenter that resolves the discreteness problem. But an experimenter represented by a state governed solely by Process 2 has nothing discrete about him: his brain is a continuous smear with no dynamically defined dividing lines.

The founders of quantum theory (and von Neumann) recognized this basic problem of principle, and in order to resolve it went to a radical and revolutionary extreme: they introduced human experimenters with efficacious free choices into the physical theory. This was a giant break from tradition. But the enormity of the problem demanded drastic measures. Because such powerful thinkers as Wolfgang Pauli and John von Neumann found it necessary to embrace this revolutionary idea, anyone who claims that this unprecedented step was wholly unnecessary certainly needs to carefully explain why. This has not yet been done. (Further details are given in part 2 section 2.)

Although bringing human agents into the dynamics is certainly quite contrary to the ideas of classical physics, the notion that our streams of consciousness play a causal role in the determination of our behaviour is not outlandish: it is what one would naturally expect. Orthodox quantum theory solves the basis problem in a way that allows our conscious thoughts to affect our physical actions.

Bohm’s Pilot-Wave Model.

Bohm's pilot-wave model (Bohm, 1952) is an attempt to supplement Process 2 by adding an extra element, not involving mind, that does the job that the mind-driven Process 1 does in the orthodox interpretation.

One main objection to Bohm’s model is that it adds no testable content. It adds to the mathematical machinery of quantum theory a theoretical substructure built on a resuscitation of the classical idea of a world of point particles (atomic-sized planet-like objects). The function of his postulated world of classically conceived particles is to determine, in accordance with classical concepts, what our experiences will be. Because there is, according to Bohm’s model, only one such classical world, there will be only one experience, not the infinite host of them that Process 2 seems to generate.

To make this idea work, in a way compatible with the predictions of quantum mechanics, the motion of each particle in the universe, at each instant of time, is obliged, in general, to depend sensitively on the locations of every other particle in the universe at that instant. But the location of every particle in the universe at the present instant “now” can never be known to us. So the extra “classical” structure postulated by Bohm adds no predictive power. It may give some physicists and philosophers a warm feeling of “understanding”, but this understanding can never be tested or concretely used.

I once asked Bohm how he answered Einstein's charge that his model was "too cheap". He said that he completely agreed! Notice, in this connection, that in the last two chapters of his book with Hiley, Bohm goes beyond this simple model, and tries, in terms of his ideas of implicate and explicate order, to come to grips with the deeper problems that are being considered here. But Bohm's extra ideas are considerably less mathematical, and much more speculative and vague, than the pilot-wave model that many other physicists want to take more seriously than did Bohm himself.

Bohm ultimately appreciated the need to deal more substantively with the problem of consciousness. He wrote a paper on the subject (Bohm, 1986, 1990), which ended up associating consciousness with an infinite tower of pilot waves, each one piloting the wave below. But the great virtue of the original pilot-wave model, namely the fact that it was simple and deterministic with cleanly specified solvable equations, became lost in this infinite tower.

Over and beyond these problems with consciousness there is the technical problem that a Bohm-type deterministic model apparently cannot be made to accommodate particle creation and annihilation, which is an important feature of the actual world in which we live. Completing the dynamically incomplete physical [Process 2] description provided by quantum theory by adding a classically conceived deterministically specified physical world, instead of choices made by agents and by nature, has never been achieved, except in an idealized non-relativistic world in which there is no creation and annihilation of particles.

Spontaneous-reduction models

One other kind of way of completing the quantum dynamics without bringing in "The Observer" is to introduce "spontaneous reductions". These are reductions that act according to some specified mechanical or statistical rule that does not involve consciousness, but that keeps a leash in the tendencies of the centers of large objects to become uncertain. The spontaneous reductions keep trimming back the spreading clouds so that the spread in the quantum mechanically specified locations of the (center of the) large objects become negligible on the scale of visible objects. A model of this kind was originally proposed by Ghirardi, Rimini, and Weber, and has been pursued vigorously by Philip Pearle. The bottom line is that it has not been possible to construct a model of this sort that accommodates particle creation and annihilation and is relativistically invariant in the same satisfactory sense that the orthodox von Neumann (Tomonaga-Schwinger) theory is relativistically invariant. A quasi-relativistic theory of this kind has recently been proposed by Pearle (2005), who expounds also on the inability of these spontaneous-collapse models to do better.

Overall, the situation as regards non-orthodox proposals is that, in spite of intense effort, none of them have been developed to a point that even their protagonists regard as really satisfactory, and it appears to me that prospects do not look bright for any of them.

These kinds of models developed by physicists emphasize, not very surprisingly, the physical/mechanical aspect of nature, and take the psychological aspect to be some peculiar special phenomena arising in connection with complex biological systems. Thinkers with a more mind-centered orientation tend, not very surprisingly, to regard the entire physical universe as arising within the broader context of a pervading reality that is generalization of human consciousness, and that somehow sets the initial conditions, and the rules and laws, of the physical universe; and that manifests aspects of itself in suitable physical systems, such as are provided by biological nervous systems. Indeed, the fundamentally physical/mechanical approach is left with the embarrassing question of how it fixed its own rules of operation and its own initial conditions. These puzzles seem to take us to, or beyond, the boundaries of science as we know it, which emphasizes again the importance of pursuing intensively the effort to understand all domains where pertinent data is being generated by aggressive scientific experimentation.

12. Despised Dualism

Scientists in different fields are, to some extent, free to use concepts that appear to work for them, without regard to other scientific disciplines. However, many of the greatest advances in science have come from unifying the treatments of neighboring realms of phenomena. We are now engaged a great scientific endeavor to rationally connect the neurophysiological and psychological aspects of the conscious brain. The problem is to understand, explain, or describe the connections between two realms that are conceived of and described in two very different ways. What seems pertinent is that basic physics *was forced by the character of empirical phenomena itself* to an incredibly successful way to link these *same* two realms. It seems reasonable to *at least try* to apply the solution discovered by physicists to the parallel problem in neuropsychology. Why should this natural and reasonable idea of applying to neuropsychology this idea so successful in physics be so scorned?

Contemporary physics is essentially psychophysical, hence dualistic. Dualism is seen as a bête noire by many philosophers. Hence the quantum approach tends to be peremptorily rejected because it belongs to this despised category. But why are dualistic theories held in such contempt? There is an historical reason.

I shall begin with a brief summary, abstracted from Nahmias (2002), of the principal developments in psychology during the twentieth century.

In 1898 the introspectionist E.B. Titchener delineated the proper study of psychology as the conscious mind, defined as “nothing more than the whole sum of mental processes experienced in a single lifetime.” And: “We must always remember that, within the sphere of psychology, introspection is the final and only court of appeal, that psychological evidence cannot be other than introspective evidence. ”

However, the psychologist William James (1892), who used introspection extensively, but recognized a causal link of consciousness to brain process, lamented that psychology had not developed any laws: “We do not even know the terms between which the elementary laws would obtain if we had them.”

J.B. Watson, emphasizing the failures of introspection to achieve reliable results, went to the opposite extreme. He began his 1913 behaviourist manifesto with the words: “Psychology as the behaviourist views it is a purely objective experimental branch of natural science. Its theoretical goal is the prediction and control of behaviour. Introspection forms no essential part of its methods, nor is the scientific value of its data dependent upon the readiness with which they lend themselves to interpretation in terms of consciousness.”

The behaviourist movement made rapid gains and in 1917 H. W. Chase wrote a summary of the year’s work on “Consciousness and the Unconscious” in which he reports:

“There can be no question that consciousness is rapidly losing its standing as a respectable member of the psychologist’s vocabulary. Titchener in the preface of his new book says: I have avoided the use of the word ‘consciousness.’ Experimental psychology has made a serious effort to give it scientific meaning, but the attempt has failed, the word is too slippery, and so is better discarded.”

Technical difficulties with behaviourism began to occur and continued to mount, but, in Nahmias’s words, “It was not until Chomsky’s 1959 famous review of Skinner’s *Verbal Behaviour* that the tide fully turned against trying to treat language, including reports about human experience, just like any other behaviour.” This turning of the tide meant that behaviourism failed precisely for the point at issue: the connection of physical process to conscious process. Yet the pariah status assigned to dualism by behaviourists lingered on after the fall of behaviourism, and it still persists today. Yet why should this bias continue after the demise of the discredited philosophy that spawned it?

Daniel Dennett (1991) gives a reason. His book “Consciousness Explained” has a chapter “Why Dualism Is Forlorn”, which begins with the words:

“The idea of mind as distinct …from the brain, composed not of ordinary matter but of some other special kind of stuff is dualism, and it is deservedly in disrepute today. … The prevailing wisdom, variously expressed and argued for is materialism: there is one sort of stuff, namely matter---the physical stuff of physics, chemistry, and physiology---and the mind is somehow nothing but a physical phenomenon. In short, the mind is the brain.”

Dennett then asks: “What, then, is so wrong with dualism? Why is it in such disfavor?” He answers:

“A fundamental principle of physics is that any change in the trajectory of a particle is an acceleration requiring the expenditure of energy …this principle of conservation of energy … is apparently violated by dualism. This confrontation between standard physics and dualism has been endlessly discussed since Descartes’s own day, and is widely regarded as the inescapable flaw in dualism.”

This argument depends on identifying “standard physics” with nineteenth century physics. But the argument collapses when one goes over to contemporary physics, in which, due to the Heisenberg Uncertainty Principle, trajectories of particles are replaced by cloud-like structures, and in which conscious choices can influence physically described activity without violating the laws of physics. *Contemporary physical theory allows, and its orthodox von Neumann form entails, an interactive dualism. There is no valid science-based reason to reject as either unscientific or useless the conception of the human person based on the psychophysical conceptions of orthodox twenty-first century physics, rather than on the known-to-be-false materialist principles of nineteenth century physics.*

13. John Searle on Mind, Free Will, and the Quantum.

John Searle is a philosopher of mind who has strongly challenged the materialist philosophies that have dominated academic thinking about mind for many years. On the basis of the notion of the causal closure of the physical, materialists have sought to eliminate effectively, in one way of another, that inner first-person qualitative feel of our waking lives. Searle insists that philosophers must integrate qualitative subjective reality into philosophy, rather than constructing evasive maneuvers designed to leave it out. Yet Searle rejects even more insistently the precepts of Cartesian dualism, and has tried hard to find a rationally coherent alternative to those two alternatives. Von Neumann quantum ontology is, I believe, the alternative he has been seeking.

Searle has recently written a new book *MiND, a brief introduction*. In it he describes briefly, in his usual lucid way, the chief topics of the philosophy of mind, namely the mind-brain connection, consciousness, intentionality, mental causation, free will, perception, and the self. He sketches out his reasons for believing that the views of most other philosophers on these subjects are terribly mistaken, and then presents his own views. By and large, Searle’s answers lead in the direction of the quantum approach described in this book. However, he develops his approach while adhering to the classical-physics conception of what basic science says. He admits at the beginning of his book that quantum theory may provide a way of dealing with unresolved problems, and cites (an earlier draft of) this book in that connection, but says he will ignore the quantum approach because he does not understand it. (p. 46). Later on, however, he does try to see whether quantum theory will help resolve some difficulties, and concludes that it will not. But that conclusion is based on a serious misunderstanding of what quantum theory is and does.

Generally, one cannot understand a fundamentally new idea until one sees how to reconcile it with one's understandings of closely related topics. Thus Searle's new summary of the whole field of philosophy of mind from a viewpoint close to the quantum view provides me with an opportunity to expand the reader's understanding of the quantum approach by explaining how the transition from classical physics to quantum physics impacts upon the chief topics in philosophy of mind.

I have focused in the present book upon a single key technical point, namely the fact that quantum theory does more than merely introduce elements of randomness and uncertainty into physics. More importantly it entails the existence of human conscious choices that are not themselves fixed by any yet-known laws, but that can strongly influence human behaviour. The aim of this chapter is to explain how this radical change in basic physics impacts upon some of the arguments put forth by Searle. Overall, the effect of this shift in physics is to support Searle's effort to integrate the first- and third-person aspects of nature---rather than reducing one to the other---by showing how this integration is achieved in contemporary physical theory, and explaining how the problems encountered by Searle are resolved by replacing the known-to-be-false precepts of classical physics by the empirically supported precepts of orthodox quantum physics.

In the first one-third of his book Searle gives a quick survey of the main ideas and arguments in contemporary philosophy of mind. He then notes that

> In most philosophical subjects there is no sharp division between what the professionals believe and the opinions of the educated public. But on the issues discussed in this book there is an enormous difference between what most people believe and what the professional experts believe. I suppose most people in the Western world believe in some form of dualism. …[but] Almost without exception, the professional experts in the field accept some version of materialism. (p.12)

The reason for this disparity is easy to see. Science and religion are the twin foundations of the beliefs of the educated Western public. Western science was erected upon René Descartes' separation of the human mind from the human brain, i.e., on a dualistic conception of human agents that is compatible with Christianity. Thus Western science, at least at its inception, and Western religion were united in their support of the dualistic idea that there are two differently described aspects of nature, the mental and the physical, which interact within human brains. On the other hand, professional philosophers, while essentially unified in their opposition to dualistic ideas, have been unable to arrive at a rationally coherent materialistic account of nature. Instead of collectively presenting to the public a clearly formulated materialistic conception of the world, they are incessantly demolishing each other's attempts to do so.

Searle has moved beyond this obsession of philosophers with trying to explain how materialism can be true and dualism false. At the end of the survey mentioned above Searle concludes that "we know independently that both what dualism is trying to say and what materialism is trying to say are true. Materialism is trying to say that the world consists of physical particles in a field of force. Dualism is trying to say that there are irreducible and ineliminable mental features of the world, consciousness and intentionality, in particular" (p. 106)

Searle's solution of the mind-brain problem is essentially to assert that nature is causally materialistic and ontologically dualistic. The dualistic aspect inheres in the fact that consciousness has a "first-person ontology" while its neural substrate has a "third-person ontology." Thus conscious activities and neural activities are ontologically different. Both are real, but the former cannot be eliminated or reduced to the latter because the two are ontologically different.

Searle's claim that nature is causally materialistic rests essentially on his recitation of "known facts": "We know for a fact that all of our mental processes are caused by neurobiological process" (p. 114): "We know for a fact that they [my feelings of thirst] are caused by neural processes" (p.115). He goes on:

> But what are these feelings of thirst exactly? Where and how do they exist? They are conscious processes going on in the brain, and in that sense they are features of the brain. … Just so this does not sound like I am vaguely talking about how things might be as opposed to how they actually are in fact, let me nail the whole issue down to reality by summarizing some of what we know about how brain processes cause feelings of thirst. Suppose an animal gets a shortage of water in his system. The shortage of water will cause 'saline imbalances' in the system, because the ratio of salt to water is excessive in favor of salt. This triggers certain activities in the kidney. The kidneys secrete rennin, and the rennin synthesizes a substance called angiotensin 2. This substance gets inside the hypothalamus and affects the rate of neuron firings. As far as we know the differential rates of neuron firings cause the animal to feel thirst. … All conscious states are caused by lower-level neuronal processes in the brain …and they exist as biological features of the brain system. (p. 112/113)

Most of this scenario is presented as completely known and certain. But one step is curiously different from the others. All the causal steps from molecules up and including neuron behaviour, but not including the appearance of the *feeling* (of thirst), are described in terms of physical substances, composed of physical particles, and are presented as known certainties, presumably because such particles, and hence the structures built out of them, are controlled by the laws of physics, whereas the fact that the changed rates of neural firings "cause the animal to feel thirst" is qualified by "as far as we know". Indeed, there is, according to the precepts of classical physics, a big difference between the claim that one physically described process *causes* another physically described process and the claim that a physically described process *causes* a psychologically described feeling to occur. The laws of classical physics directly specify causal connections between different physically described processes, but do not directly specify any causal connection between the physically described aspects of nature, as described in physics text books, and the psychologically described "feelings" that occur in our streams of consciousness. Indeed, the universally recognized great virtue of classical physical theory was precisely that its physical laws avoided any mention of psychologically described entities. But the claim that changed rates of firing *cause* feelings of thirst seems, on the face of it, to suggest the need for causal laws of a different kind, laws that connect ontologically different kinds of things. Searle tries to dodge that conclusion, and get effective psychophysical causation from purely physical causation, by denying the idea (attributed to Descartes) that no reality can be both physical and experiential. I shall argue that this dodge fails: psycho-physical causation is needed, and quantum theory provides it.

Searle states his ideas about consciousness as four theses (p. 113):

> 1 Conscious states, with their subjective, first-person ontology are real phenomena in the real world. We cannot do an eliminative reduction of consciousness showing that it is just an illusion. Nor can we reduce consciousness to its neurological basis, because such a third-person reduction would leave out the first-person ontology of consciousness.
>
> 2. Conscious states are entirely caused by lower level neurobiological processes in the brain. Conscious states are thus *causally reducible* to neurobiological processes. They have absolutely no life of their own, independent of neurobiology. Causally speaking, they are not something "over and above" neurobiological process.
>
> 3. Conscious states are realized in the brain as features of the brain system, and thus exist at a level higher than that of neurons and synapses. Individual neurons are not conscious but portions of the brain system composed of neurons are conscious.
>
> 4. Because conscious states are real features of the real world they function causally. My thirst causes me to drink water for example. I will explain in detail how this works in chapter 7, Mental Causation.

Searle claims that "we know" all of these things to be true, but then asks: "Why then does this apparently obvious solution encounter so much resistence?" (p. 114). He answers that the difficulty is with "the traditional categories": He claims, essentially, that the problem is with our language and the associated concepts. I shall argue that the error is rather with the acceptance of some known-to-be-false concepts of classical physics.

One problem with Searle's scheme is to understand why there is not "causal over-determination." If the materialistic level of description is already, by itself, causally complete, yet "My [ontologically different] conscious thirst causes me to drink water" then the second set of causes must be redundant. In Searle's words the problem is this: "supposing… that the mind did play a causal role in producing our bodily behaviour, … seems to get us out of the frying pan into the fire, because now it looks like we have too many causes. It looks like we have what philosophers call 'causal overdetermination.' It looks like there would be two separate sets of causes making my arm go up, one having to do with neurons the other having to do with conscious intentionality."(p. 206)

Searle addresses this crucial issue in chapter 7, Mental Causation. He lists four propositions (p.207):

1. The mind-body distinction: the mental and the physical form distinct realms.

2. The causal closure of the physical: the physical realm is causally closed in the sense that nothing nonphysical can enter into it and act as a cause [in the physical realm].

3. The causal exclusion principle: where the physical causes are sufficient for an event, there cannot be any other types of causes of that event.

4. Causal efficacy of the mental: mental states really do function causally [in the physical realm.]

I have added the bracketed phrases [in the physical realm], because an action of mental states in the mental realm would not be pertinent in this context.

The final three propositions are set forth as essentially known or "accepted" truths. Proposition 2, the causal closure of the physical, is supposed to be what is known. Proposition 3 denies causal over-completeness. And Searle accepts Proposition 4 on the basis of his direct impression of the causal efficacy of his conscious efforts to, say, raise his arm. (p. 203), buttressed by the evolutionary argument (p.233) that mental processes would have no natural tendency to develop---as they evidently have done during the evolution of our species---if they were causally inert in the physical world.

Searle notes that these four propositions are inconsistent, and claims that "The mistake is expressed in proposition 1, the traditional mind-body distinction." Thus he uses the inconsistency of the four propositions to discredit Descartes' idea that the mental and physical form ontologically distinct realms. This allows him to conclude that the traditional vocabularies, categories, and meanings must be redefined and restructured, in order to maintain the three "accepted" truths, which he finds more congenial than the metaphysical proposals of Descartes.

Actually, Propositions 1,2, and 4, by themselves, are already inconsistent. If, in accordance with Proposition 2, nothing nonphysical can act as a cause in the physical realm, and, as asserted by Proposition 4, mental states do function causally in the physical realm, then mental states must be physical, and proposition 1 must be false. Thus Descartes is proved wrong, and we must, Searle concludes, abandon the traditional metaphysical categories.

However, Proposition 2, in the form stated, is logically unsatisfactory. The concept of something nonphysical "entering into" the physical realm is obscure. How can a nonphysical thing enter the distinct realm of physical things. That is a contradiction. The apparently intended meaning of Proposition 2 is simply that "nothing nonphysical can act causally in the physical realm." This form of proposition would still allow the contradiction to follow. But, like the earlier one, it renders Proposition 3 superfluous: Yet the argument was supposed to address the problem of causal over-determination. Hence Proposition 3 needs to enter.

Another problem with Proposition 2 is that it does not express the *usual* classical meaning of the "causal completeness of the physical," which is simply that the physical description is causally complete by itself This is what is usually meant by the causal completeness of the physical. No explicit mention is made of nonphysical realities.

A rational argument that does use Proposition 3 is obtained if, in accordance with Searle's overall stance, one accepts classical physics, and simply takes the "causal closure of the physical" to mean what it means in classical physics:

> 2'. The causal closure of the physical: the physical world is causally closed, in the sense that all physical events are entirely determined (from earlier physical conditions) by physically described causes,

This proposition, taken from classical physics, combines with the other *three* to give a contradiction: If in accordance with 4 the mental can causally affect the physical, and in accordance with 2' the physical is entirely causally determined by the physical, and in accordance with 3 there is no causal over-determination then the mental cause must be physical, and proposition 1 must fail.

But why is Proposition 1 the mistake, as Searle claims? The neurobiological and mental aspects are asserted by Searle to be *ontologically* different. But then they belong to different *ontological* realms, and hence to different (distinct) realms, in agreement with Proposition 1. That is, Proposition 1 seems to follows directly from Searle's main thesis that mind and brain are ontologically different. Searle wants to maintain also Proposition 3, that there is no causal over-determination, and Proposition 4, that our conscious intentional thoughts really do affect our actions. On the other hand, Propositions 2 and 2', although true in the classical-physics approximation are not entailed by contemporary physics. Thus Searle's argument backfires Carefully examined it leads not to the drastic conclusion that our basic categories of thought must be abandoned, because they lead to contradictions, but rather to the simpler conclusion that the classical-physics approximation is inadequate for treating the conscious brain: one needs to go beyond that *approximation*, and the doctrine of the causal closure of the physical that it entails

Searle's ideas, apart from his insistence on the causal closure of the physical, resemble the ideas of orthodox von Neumann quantum theory, ontologically construed. These are that the psychologically and physically described aspects of scientific practice are to be treated as ontologically distinct features of reality; that the former are causally efficacious in the physical world; and that human conscious experiences are closely connected to high-level features of associated human brains.

Searle enunciates later on what he takes to be conclusive arguments against dualism (p. 132):

1. No one has ever given an intelligible account of the relationship between these two realms.

2. The postulation is unnecessary. It is possible to account for all of the first-person facts and all the third-person facts without the postulation of separate realms.

3. The postulation creates intolerable difficulties. It becomes impossible to explain how mental states and events can cause physical states and events. In short, it is impossible to avoid epiphenomenalism.

As regards point 1, Von Neumann's account of the relationship between these two realms is eminently intelligible: Von Neumann was an extremely rational and careful thinker. I find his account completely intelligible, and have tried in this book to convey in non-mathematical terms what von Neumann said with the aid of precise mathematics.

As regards point 2, physicists discovered around 1925 that in order to account for a vast array of empirical facts in the domain of atomic physics they had to replace the mathematical representations of the *intrinsic* (physical) descriptions of systems by mathematical representations of probing actions *performed upon those systems* by observing systems *external* to them. To construct a practically useful theory they brought in inputs from the stream of consciousness of the observing systems. Thus *even in the domain of pure physics* it is not evident that postulate 2 holds. So how can it be a conclusive argument against dualism.

As regards point 3, the quantum laws are, as a matter of fact, *perfectly suited* to account for the causal effects of a person's conscious effort upon his brain, and thence upon his physical actions. The foregoing parts of this book have explained how the quantum laws allow the physical effectiveness of our conscious acts to be understood in a natural way.

Searle claims that in order to accommodate his presumptions "we have to abandon the assumptions behind the traditional vocabulary." (p.106) He says he wants "to suggest that we should not accept the traditional terminology and the assumptions that go with the terminology. Expressions like 'mind' and 'body', 'mental' and 'material' or 'physical' as well as reduction,' 'causation,' and 'identity,' as they are used in discussions of the mind-body problem are the source of our difficulty and not the tools for its resolution." (p. 108)

This linguistic approach is in line with the notion of "philosophy as linguistic analysis" that dominated philosophy during much of the twentieth century. *However, the source of the vexing problems in philosophy of mind is not the language: it is rather the use of antiquated physics.* The old words can be used in a normal way, with normal meanings, without contradictions or difficulties, provided one accepts concepts of twentieth century physics.

How does this acceptance of contemporary physics affect the rest of the arguments given in Searle's book?

Viewed from the quantum perspective most of the general problems mentioned in Searle's book simply disappear, or are directly answered by the features of the quantum ontology already described. But rather than dwelling on the many relatively minor issues covered by Searle I shall go directly to the main issue: Free Will.

Searle bases his inquiry into "free will" on an examination of the conscious process of deciding to act in a certain way on the basis of "reasons." (p. 212) He emphasizes that the results of our human deliberations involving reasons are not conclusive, in the way that the conclusions that follow from the precepts of classical physics are conclusive. He notes that "It is essential to see that the functioning of human intentionality requires rationality as a structural constitutive organizing principle of the entire system." (p. 213)

Before delving into this matter I need to dispel some prevailing misconceptions about the quantum nature of the world by commenting on Searle's analysis of free will.

Searle admits at the outset of his discussion of the problem of the nature of free will that he has no solution. (p. 215) But he examines the question in order to clarify it.
.

Searle begins by saying:

> There is a special problem about free will because we have two absolutely irreconcilable convictions, each of which seems to be completely correct and, indeed, inescapable. The first is that every event that occurs in the world has an antecedently sufficient cause. Our second conviction, that we do in fact have free will, is based on certain experiences of human freedom. We have the experience of making up our mind to do something and then doing it. It is part of our conscious experiences that we experience the causes of our decisions and actions, in the form of reasons for those decisions and actions, as not sufficient to force the actual decisions and actions. (p. 216)

The origin of the "conviction" that each definite happening has an antecedently sufficient cause is evidently some metaphysical idea, such as the idea that classical physics is true, or the idea that no definite happening can just simply pop into being without there being some "reason" why this particular thing has happened instead of something else.

The origin of the conviction that we have free will is directly experiential. Searle notes that an experienced reason to act in a certain way *may or may not* be followed by a decision to act on the basis of that reason. He notes, moreover, there is, within the stream of consciousness, also *the experience of a causal gap*: the antecedent reason is not experienced as being coercive or sufficient with respect to the choice that follows That is, *within the realm of experience* there is, he notes, no determinism: there are experienced causal gaps. The actual making of the decision seems to be infected by an element of indeterminateness: we feel uncompelled to decide in accordance with the dictates of the antecedent reasons. Searle presents an analysis that ties this indeterminateness that he has identified, *regarded as a bona fide reality*, to the randomness in quantum theory.

According to Searle, "Our experience of the gap [in strict causation] is the basis of our conviction that we have free will" (p. 218) i.e., it is the basis of our conviction that our willful conscious choices are in fact "free". Of course, a completely natural explanation of our experiencing of a causal gap is that our stream of consciousness grasps only certain high-level features of the fundamental causal process, and that these experienced features alone will be insufficient to specify completely the causal progression, which, however, is (or at least can be) strictly determined at the fundamental level. So the causal linkages that we directly experience must certainly be expected to be non-coercive, even if the fundamental causal process is really fully coercive. This simple causal explanation of "our experiencing of a causal gap" would seem to render *our experiencing* of a causal gap a matter completely unworthy of further serious attention.

Of course, this explanation *could* be wrong. It cannot be strictly ruled out that the indeterminateness we feel is veridical. The physically described brain just conceivably might not completely determine our every thought and action. But

Searle declares that *“If freedom is real then the [causal] gap has to go all the way down to the level of neurobiology.”* (p.228)

Searle argues, in effect, that this possibility needs to be seriously explored for the following reason: our real lives are based on the presumption that our choices are “free” in the sense of not being mere products of mindless mechanical processes churned out by unknowable and unknowing tiny bits of matter. He says:

> Whenever we decide to act voluntarily, which we do throughout the day, we have to decide or act on the presumption of our own freedom. Our deciding and acting are unintelligible to us otherwise. (p. 219)

Arguing on the basis of the need for the intelligibility of our lives is not completely unreasonable. In the end a theory of nature is more useful to us if makes things intelligible. There is a certain unintelligibility and irrationality about adopting, in our real lives a conception of nature that asserts that we are mechanical robots, completely at the mercy of automatic mindless neuronal processing, while acting as if the conscious choices that we struggle so hard to make are really made by *us*, instead of by unthinking atoms. Consequently, a theory, based securely on contemporary science, that allows us to understand how our decisions are made *by we ourselves, as we know and understand ourselves,* rather than by mindless atoms, would be a worthwhile achievement. It might quell the turmoil that has engulfed philosophy since the invention by Isaac Newton of classical physics, whose blind acceptance renders our lives unintelligible.

This argument motivates Searle’s consideration of quantum mechanics, in parallel with a first alternative, more favored in his view:

> **Hypothesis 1: Determinism and the Mechanical Brain**
>
> On the first hypothesis we have to assume that the brain is a machine in the traditional old-fashioned sense of car engines, steam engines, and electric generators. It is a completely deterministic system, and any appearance of free will is an illusion based on our ignorance, so that this hypothesis fits well with what we tend to believe about nature and biology in general. The brain is an organ like any other, and it has no more free will than do the heart or the liver or the left thumb. (p.229/30)
>
> **Hypothesis 2: Indeterminism and the Quantum Brain**
>
> Hypothesis 1 is comforting in that the brain turns out to be a machine like any other. But on hypothesis 2 it is not at all clear what kind of mechanism the brain will have to be for the system to be nondeterministic in the right way. But what exactly is the right way? We have to suppose that consciousness plays a causal role in determining our decisions and our free actions, but we

> also have to suppose that that causal role is not deterministic. That is, it is not a matter of sufficient conditions. Now the creation of consciousness at any instant of time is a matter of sufficient conditions, so what we are supposing is that the left-right movements of neurobiological processes through time are not causally sufficient, That is, each stage of the neurobiological process is not sufficient by itself to determine the next stage by way of causally sufficient conditions. Suppose that the explanation of each stage by the preceding stage depends on the fact that the whole system is conscious and has the particular type of consciousness that manifests a gap, that is, voluntary consciousness. But what would such a system look like? We are assuming that the brain is, at its most basic level, nondeterministic; that is, that the (causal) gap that is real at the top level goes, so to speak, all the way down, down to the level of the neurons and subneuronal processes. Is there anything in nature that suggests even the possibility of such a non deterministic system? The only part of nature that we know for a fact today, at the time that I write this, is the quantum mechanical part. However, it is a bit misleading to call that a part because it is the most fundamental level of physics, the most basic level of the physical particles. At the quantum level the state of the system at t_1 is only causally responsible for the state of the system at t_2 in a statistical, nondeterministic manner. Predictions made at the quantum level are statistical because there is a random element. (p. 230/31)

I have included this long passage because it indicates how, in Searle's thinking, the demand that life be intelligible leads to the need to bring quantum effects into the understanding of mind. Most neuroscientists and philosophers of mind fiercely resist the idea that quantum effects---which seem so remote from their fields as they are currently practiced---could really be essential to the solution of the mind-brain problem. But this passage presents Searle's reasoning, starting from philosophy of mind considerations, and the demand for the intelligibility of our real lives, that leads him *reluctantly but rationally* to the conclusion that quantum effects may be important to an understanding of the connection between mind and brain.

Searle then goes on to say: "It has always seemed to me in the past that the introduction of quantum mechanics into the discussion of free will was totally irrelevant for the following reason: free will is not the same as randomness. Quantum mechanics gives us randomness but not freedom. That argument used to seem convincing to me, but now it seems to me that it commits the fallacy of composition." The fact that there is randomness at some atomic level does not entail that the entailed lack of determinism is manifested at high-levels also as randomness. "In a word, the randomness at the microlevel…does not imply that the [resulting indeterminate] conscious phenomena are random." (p. 232) Then, after summarizing the input assumptions, Searle says "we have to suppose there is a quantum mechanical component in the explanation of consciousness. I see no way to avoid this conclusion." (p. 232)

However, he then immediately says: "Of course, Hypothesis 2, the hypothesis that the random indeterminacy at the quantum level leads us to an indeterminacy of a nonrandom kind at the conscious level, seems very unlikely and implausible … given all we know about nature Hypothesis 1 seems much more plausible."

It is not clear who the "we" are to whom, given all "we" know about nature", the application of the classical-physics approximation to the dynamics of a conscious brain seems much more plausible. Physicists undoubtedly are not included. What his argument does point to, however, is a conflict between what most philosophers of mind believe and the demand for an intelligible understanding of our real-life actions. It is this conflict that leads Searle to the conclusion that quantum mechanical effects may be important to an understanding of the mental side of our being.

Searle notes another argument in favor of Hypothesis 2: "An enormous amount of the biological economy is devoted to conscious rational decision making." "That we should have these massive experiences of freedom if there is no biological cash value to the experience would seem like an absurd result from an evolutionary point of view." (p.233)

Searle's main objection to Hypothesis 2 is, again, this: "Of course, Hypothesis 2, the hypothesis that the random indeterminacy at the quantum level leads us to an indeterminacy of a nonrandom kind at the conscious level, seems very unlikely and implausible. "

That scenario is indeed unlikely and implausible. But it is based on a serious, though extremely common, misunderstanding of quantum mechanics. It assumes that the *randomness* of quantum mechanics comes in at the atomic level. That is not correct! In quantum theory the dynamics at the atomic level is deterministic and nonrandom, as is the dynamics at all levels that are described exclusively in purely physical terms. The randomness enters in principle only in connection with an *outcome of an observation*. An observation and its outcome are described in *a different kind of language*, and involves either a measuring device, whose physical response can be "observed" by an agent, or a brain, whose physical response can be "experienced" by the agent to whom the brain belongs.

The element of *freedom* in quantum theory *pertains to the agent's Process 1 choice of which observation to make*. This freedom is not conceived to be built out of the "elements of randomness" associated with the *outcomes* of these "freely chosen questions" determinded by Process 3. The *freedom of choice* of which question to pose---of which action to take---is opened up by the *uncertainty principle*, whereas the element of randomness is associated with the indeterminateness of nature's choice of an *outcome* of the freely chosen question. The *freedom* of our human choices is one aspect of orthodox quantum theory, and the *randomness* in nature's choice of outcome is another.

The problem of Free Will divides into two parts. The first part is: What are the physical consequences of our treated-as-free conscious choices? The answer to this question has been extensively discussed in this book. The second part is: From what considerations, or reasons, or causes, do these treated-as-free choices arise? What is the nature of Process 4? The answer is not constrained by orthodox quantum theory. Quantum mechanics is mute on this issue, beyond the demand that the answer be compatible with any pertinent available evidence.

Following Searle, let us consider what happens when I try to decide how to vote when I go to the polling booth.

My *feelings* about what is happening, as I review these complex considerations, in order to make my choice, is that I *feel* a weight for each idea, and am able to make an evaluation based on the net effect of all of these feels together. This evaluation, which seems to emerge from a complex feeling that somehow integrates and combines a lot of prior feelings, seems to call forth a certain intention to act, which then calls forth an action, provided a final assent or a sufficient effort is summoned ..

That is what *seems* to be what is happening. But what is really going on?

Orthodox quantum theory accepts *as given* the fact that there are human agents that have streams of conscious thoughts, and that the mechanistic Process 2 evolution of the physical system is interrupted by Process 1 events. If we want to speak about "what is really going on" then, according to policy adopted here, we turn to the von Neumann ontology, in which Process 2 governs the evolution of the entire universe, including our brains, apart from the Process 1 interventions, and the feedbacks that result from these interventions..

A minimalist model of the Process 4 mechanism that selects when a Process 1 event occurs, and what that event will be, was described in Stapp (1999). In that model a purely mathematical/physical rule was given that defined *a sufficient condition* for specified psychophysical event to occur in a given observing system. The particular rule described there is not particularly important. However, it shows that there could exist *purely mechanical* sufficient conditions for the occurrence of a particular Process 1 event at a particular time. Such a rule could probably allow some of the mechanistic models of the mind-brain system that cognitive scientist have been developing over the past few decades to be reconciled with the laws of physics: they need not be completely discarded in order to make them consistent with the basic known laws of physics.

The existence of purely mechanical *sufficient conditions* for a Process 1 psychophysical event to occur could help account very strong effects of brain processes on conscious processes, and also for the emergence of consciousness in primitive life forms. Once it is granted that such sufficient conditions may exist there seems to be no reason in principle why some of the classical modeling done by cognitive scientist could not be made compatible with contemporary physical theory.

An essential difference, however, between classical-type models and quantum models is that in the quantum case the sufficient mechanical conditions need not be also necessary. Psychological aspects of the events could cause *extra* Process 1 events to occur. In particular, a *feeling* associated with an occurring event could, within the quantum framework, cause an almost immediate re-enactment or repetition of the Process 1 event. This could trigger a quantum Zeno effect holding action. In such a situation *the conscious feeling that triggers the repition* would be having an effect that could guide the action of the agent in a manner gentle superposed upon the underlying essentially mechanical process. In this way our conscious efforts and concepts could be steering the physical process in roughly the way that they seem to us to be doing.

Such an integration of a classical model into contemporary physical theory would offer the benefits of not only making the model physically acceptable, but of also resolving several difficult questions, such as why is conscious present in the world if it is not present in the causally sufficient basic physical theory; and why is consciousness present if it cannot do anything not already done by the mechanically described aspects of the theory; and why should nature perpetrate this crazy hoax that makes us believe that our thoughts can make a difference, when even that belief itself is forced upon is by microscopically controlled mechanical motions of atoms? Accepting quantum theory banishes these questions. .

The minimalist ontology described above is not a complete ontology. I have merely translated into ordinary words what was already essentially present in von Neumann's work, and extended it by an application of the quantum Zeno effect. The successes at the many levels described in this book of this quantum mechanical conception of reality do not guarantee that it is the literally true and final answer to the question of how our minds are connected to our bodies. Having once been burned, we are rightfully wary of jumping to conclusions about the "truth" of our theoretical ideas concerning the nature of the reality lying beyond our streams of conscious experiences. Nevertheless, the fact that this putative ontology succeeds beautifully on all of these difficult points where the classical conception fails miserably, and has no known failures of its own, makes it a huge improvement over the conception of reality stemming from classical physics. It is rationally coherent model that expands the scope of agreement between theory and appearances, and is concordant with orthodox contemporary physics

14. Impact of Quantum Mechanics on Human Values

Philosophers have tried doggedly for three centuries to understand the role of mind in the workings of a brain conceived to function according to principles of classical physics. We now know no such brain actually exists: no brain, body, or anything else in the real world is composed of those tiny bits of matter that Newton imagined the universe to be made of. Hence it is hardly surprising that those philosophical endeavors were beset by enormous difficulties, which led to such positions as that of the `eliminative materialists', who hold that our conscious thoughts must be eliminated from our scientific understanding of nature; or of the `epiphenomenalists', who admit that human experiences do exist, but claim that they play no role in how we behave; or of the `identity theorists', who claim that each conscious feeling is exactly the same thing as a motion of particles that nineteenth century science thought brains and everything else in the universe was made of, but that twentieth century science has shown not to exist, at least as they were formerly conceived. The tremendous difficulty in reconciling consciousness *as we know it* with the older physics is dramatized by the fact that for many years the mere mention of "consciousness" was considered evidence of backwardness and bad taste in most of academia, including, incredibly, even psychology and the philosophy of mind.

What you are, and will become, depends largely upon your values. Values arise from self-image: from what you believe yourself to be. Generally one is led by training, teaching, propaganda, or other forms of indoctrination, to expand one's conception of the self: one is encouraged to perceive oneself as an integral part of some social unit such as family, ethnic or religious group, or nation, and to enlarge one's self-interest to include the interests of this unit. If this training is successful your enlarged conception of yourself as good parent, or good son or daughter, or good Christian, Muslim, Jew, or whatever, will cause you to give weight to the welfare of the unit as you would your own. In fact, if well conditioned you may give more weight to the interests of the group than to the well-being of your bodily self.

In the present context it is not relevant whether this human tendency to enlarge one's self image is a consequence of natural malleability, instinctual tendency, spiritual insight, or something else. What is important is that we human beings do in fact have the capacity to expand our image of "self", and that this enlarged concept can become the basis of a drive so powerful that it becomes the dominant determinant of human conduct, overwhelming every other factor, including even the instinct for bodily survival.

But where reason is honored, belief must be reconciled with empirical evidence. If you seek evidence for your beliefs about what you are, and how you fit into Nature, then science claims jurisdiction, or at least relevance. Physics presents itself as the basic science, and it is to physics that you are told to turn. Thus a radical shift in the physics-based conception of man from that of an isolated mechanical automaton to that of an integral participant in a non-local holistic process that gives form and meaning to the evolving universe is a seismic event of potentially momentous proportions.

The quantum concept of man, being based on objective science equally available to all, rather than arising from special personal circumstances, has the potential to undergird a universal system of basic values suitable to all people, without regard to the accidents of their origins. With the diffusion of this quantum understanding of human beings, science may fulfill itself by adding to the material benefits it has already provided a philosophical insight of perhaps even greater ultimate value.

This issue of the connection of science to values can be put into perspective by seeing it in the context of a thumb-nail sketch of history that stresses the role of science. For this purpose let human intellectual history be divided into five periods: traditional, modern, transitional, post modern, and contemporary.

During the “traditional” era our understanding of ourselves and our relationship to Nature was based on “ancient traditions” handed down from generation to generation: “Traditions” were the chief source of wisdom about our connection to Nature. The “modern” era began in the seventeenth century with the rise of what is still called “modern science”. That approach was based on the ideas of Bacon, Descartes, Galileo and Newton, and it provided a new source of knowledge that came to be regarded by many thinkers as more reliable than tradition.

The basic idea of “modern” science was “materialism”: the idea that the physical world is composed basically of tiny bits of matter whose contact interactions with adjacent bits completely control everything that is now happening, and that ever will happen. According to these laws, as they existed in the late nineteenth century, a person’s conscious thoughts and efforts can make no difference at all to what his body/brain does: whatever you do was deemed to be completely fixed by local interactions between tiny mechanical elements, with your thoughts, ideas, feelings, and efforts being simply locally determined high-level consequences or re-expressions of the low-level mechanical process, and hence basically just elements of a reorganized way of describing the effects of the absolutely and totally controlling microscopic causes.

This materialist conception of reality began to crumble at the beginning of the twentieth century with Max Planck’s discovery of the quantum of action. Planck announced to his son that he had, on that day, made a discovery as important as Newton’s.

That assessment was certainly correct: the ramifications of Planck’s discovery were eventually to cause Newton’s materialist conception of physical reality to come crashing down. Planck’s discovery marks the beginning of the “transitional” period.

A second important transitional development soon followed. In 1905 Einstein announced his Special Theory of Relativity. This theory denied the validity of our intuitive idea of the instant of time “now”, and promulgated the thesis that even the most basic quantities of physics, such as the length of a steel rod, and the temporal order of two events, had no objective “true values”, but were well defined only “relative” to some observer’s point of view.

Planck’s discovery led by the mid-twenties to a complete breakdown, at the fundamental level, of the classical material conception of nature. A new basic physical theory, developed principally by Werner Heisenberg, Niels Bohr, Wolfgang Pauli, and Max Born, brought “the observer” explicitly into physics. The earlier idea that the physical world is composed of tiny particles (and electromagnetic and gravitational fields) was abandoned in favor of a theory of natural phenomena in which the consciousness of the human observer is ascribed an essential role. This successor to classical physical theory is called “Copenhagen quantum theory”.

This turning away by science itself from the tenets of the objective materialist philosophy gave impetus and lent support to Post-Modernism. That view, which emerged during the second half of the twentieth century, promulgated, in essence, the idea that all “truths” were relative to one’s point of view, and were mere artifacts of some particular social group’s struggle for power over competing groups. Thus each social movement was entitled to its own “truth”, which was viewed simply as a socially created pawn in the power game.

The connection of Post-Modern thought to science is that both Copenhagen Quantum Theory and Relativity Theory had retreated from the idea of observer-independent objective truth. Science in the first quarter of the twentieth century had not only eliminated materialism as a possible foundation for objective truth, but seemed to have discredited the very idea of objective truth in science. But if the community of scientists has renounced the idea of objective truth in favor of the pragmatic idea that “what is true for us is what works for us,” then every group becomes licensed to do the same, and the hope evaporates that science might provide objective criteria for resolving contentious social issues.

This philosophical shift has had profound social ramifications. But the physicists who initiated this mischief were generally too interested in practical developments in their own field to get involved in these philosophical issues. Thus they failed to broadcast an important fact: already by mid-century, a further development in physics had occurred that provides an effective antidote to both the ‘materialism’ of the modern era, and the ‘relativism’ and ‘social constructionism’ of the post-modern period. In particular, John von Neumann developed, during the early thirties, a form of quantum theory that brought the physical and mental aspects of nature back together as two aspects of a rationally coherent whole. This theory was elevated, during the forties---by the work of Tomonaga and Schwinger---to a form compatible with the physical requirements of the Theory of Relativity.

Von Neumann’s theory, unlike the transitional ones, provides a framework for integrating into one coherent idea of reality the empirical data residing in subjective experience with the basic mathematical structure of theoretical physics. Von Neumann’s formulation of quantum theory is the starting point of all efforts by physicists to go beyond the pragmatically satisfactory but ontologically incomplete Copenhagen form of quantum theory.

Von Neumann capitalized upon the key Copenhagen move of bringing human choices into the theory of physical reality. But, whereas the Copenhagen approach excluded the bodies and brains of the human observers from the physical world that they sought to describe, von Neumann demanded logical cohesion and mathematical precision, and was willing to follow where this rational approach led. Being a mathematician, fortified by the rigor and precision of his thought, he seemed less intimidated than his physicist brethren by the sharp contrast between the nature of the world called for by the new mathematics and the nature of the world that the genius of Isaac Newton had concocted.

A common core feature of the orthodox (Copenhagen and von Neumann) quantum theory is the incorporation of efficacious conscious human choices into the structure of basic physical theory. How this is done, and how the conception of the human person is thereby radically altered, has been spelled out in lay terms in this book, and is something every well informed person who values the findings of science ought to know about. The conception of self is the basis of values and thence of behaviour, and it controls the entire fabric of one's life. It is irrational to cling today to false and inadequate nineteenth century concepts about your basic nature, ignoring the profound impact of the twentieth century revolution in science. It is irrational to act as if the contemporary scientific conception of yourself is valid while professing to believe in an essentially mechanical view that is known to be fundamentally false.

It is curious that some physicists want to improve upon orthodox quantum theory by excluding "the observer", who, by virtue of his subjective nature, must, in their opinion, be excluded from science. That stance is maintained in direct opposition to what would seem to be the most profound advance in physics in three hundred years, namely the overcoming of the most glaring failure of classical physics, its inability to accommodate us, its creators. The most salient philosophical feature of quantum theory is that the mathematics has a causal gap that, by virtue of its intrinsic form, provides a perfect place for Homo sapiens as we know and experience ourselves.

Orthodox contemporary physical theory entails no determinism that curtails your capacity to choose your actions. Instead, it institutes uncertainties that disrupt the mechanical determinism of classical physics. Yet this failure of determinism does not entail unfettered randomness! Our conscious choices can, via the laws of quantum physics, inject meaning that directs the flow of physical events. The conception of the mind-brain connection allowed by quantum theory, and naturally implemented by orthodox von Neumann quantum theory, is completely compatible with your normal intuitions about your capacity to control your actions on the basis of reasons and experience-based evaluations. An effective exercise of creative power requires a recognition of its existence. And the direction of a person's exercise of power depends upon one's understanding of his or her place in the whole.

The alternative materialist view that the universe is completely controlled by localized microscopic mechanical properties, interacting with neighboring local properties in accordance with mindless rules---and in which our conscious thoughts are seen simply as re-organized expressions of this local mechanistic order---renders totally irrational any effort to strive to achieve a future judged to be more just or equitable, or better in any way. It's like watching---in a believed-to-be-mechanical universe---a replay of yesterday's game, and spending your effort trying to make your team win.

This surrender to irrationality is an invitation to chaos. Such a renunciation of rationality might be needed, if materialism were the irrefutable consequence of validated science. But contemporary basic physics eschews mechanism, as the final word, and introduces instead a conception of human beings as active agents whose conscious decisions influence, in mathematically specified ways, the flow of perceived physical events.

This revised conception of the human person arises from a profound change in the mathematical character of the theory. The intrinsic properties of physical systems are replaced by *witnessed* or *observed* properties; and uncertainties are introduced that can be reduced by our conscious acts. These acts are "free" in the sense that they are not determined by any yet-known law, and are treated in practical applications as determined by our conscious choices.

Few things are ultimately more detrimental to our lives, and to the progress of humanity, than the incessant din that proclaims to us, and to our children, on the basis of inapplicable seventeenth century dogmas, that we are mechanical cogs in an essentially mindless universe. A debased self image begets a debased life.

15. Conclusions.

Science's proclamations about what you are, and your connection to the rest of nature, profoundly affects the intellectual milieu that undergirds both your physical situation and your conscious thoughts. It affects your values and the values of others, and thereby the entire fabric of your life.

The findings of science on these matters were radically altered during the twentieth century. That century began with science proclaiming the materialist doctrine of a fully mechanical universe; of a universe consisting of tiny realities whose interactions with immediate neighbors completely fix, from primordial initial conditions, the entire history of the universe. Our minds were reduced to impotent witnesses of the preordained mechanical process, and this proclaimed ineffectualness of our minds, backed by the authority of science, acquired important standing in our legal, social, intellectual, institutional, and philosophical systems.

That pernicious idea no longer follows from the known laws of physics. And the reason is not simply that determinism has been replaced by pure chance! Quantum mechanics provides a mechanism that can allow your mental effort to hold at bay strong mechanical forces, and inject your conscious intentions into the activity of your brain, and thence into your physical actions. This enormous shift in physics rehabilitates the notion of the causal effectiveness of mental effort that is the foundation of moral philosophy.

This rehabilitation of the notion of the efficacy of human volition, and of its place in a universe---now understood to be far more globally interconnected than any classical universe could possibly be---provides you with a picture of your mind that contrasts sharply with that ghostly and ineffectual apparition that classical physics projected. Quantum understanding converts you from a mechanical vehicle constructed by mindless genes for a purpose even they do not know, endowed for inscrutable reasons with a superfluous inept mind, to a part of reality naturally equipped by the laws of physics to inject into the physically described universe the intentions of your conscious mind. This message of empowerment follows not from vague references to unfathomable quantum mysteries, but rather from a detailed examination of the actual mathematical and interpretive structure of the theory.

How can our world of billions of thinkers ever come into general concordance on fundamental issues? How do you, yourself, go about forming opinions on fundamental issues? Do you simply accept the pronouncements of some “authority,” such as a church, a state, or a social or political group? All of these entities promote concepts about how you as an individual fit into the enduring reality that supports your being. And each has an agenda of its own, and hence its own internal biases. But then where can you find an unvarnished truth about your nature, and your place in Nature?

Science rests, in the end, on an authority that lies beyond the pettiness of human ambition. It rests, finally, on stubborn facts. The founders of quantum theory certainly had no desire to bring down the grand structure of classical physics of which they were the inheritors, beneficiaries, and torch bearers. It was stubborn facts that forced their hand, and made them reluctantly abandon the classical ideal of a mechanical universe, and turn to what perhaps should have been seen from the start as a more reasonable endeavor: the creation an understanding of nature that includes in a rationally coherent way the thoughts by which we know and influence nature. The labors of scientists endeavoring only to understand our inanimate environment produced, from its own internal logic, a rationally coherent framework into which we ourselves fit. What was falsified by twentieth-century science was not the core traditions and intuitions that have sustained societies and civilizations since the dawn of mankind, but rather an historical aberration, an impoverished world view within which philosophers of the past few centuries have relentlessly but fruitlessly tried to find ourselves. The falseness of that excursion of science must be made known, and heralded, because humans are not likely to endure in societies ruled by a conception of reality that leaves us out, or portrays us in a way that denies our essence.

APPENDICES

A1. Libet, Einstein-Podolsky-Rosen, Causality, and Free Will

This Appendix is an article of mine that appeared recently in the journal Erkenntnis.
It summarizes the technical content of this book and spells out the application of the quantum approach to the “free-will” and “causality” issues raised by an experiment performed by Benjamin Libet, and by the famous 1935 paper of Einstein, Rosen, and Podolsky

Abstract: Replacing faulty nineteenth century physics by its orthodox quantum successor converts the earlier materialist conception of nature to a structure that does not enforce the principle of the causal closure of the physical. The quantum laws possess causal gaps, and these gaps are filled in actual scientific practice by inputs from our streams of consciousness. The form of the quantum laws permits and suggests the existence of an underlying reality that is built not on substances, but on psychophysical events, and on objective tendencies for these events to occur. These events constitute intrinsic mind-brain connections. They are fundamental links between brain processes described in physical terms and events in our streams of consciousness. This quantum ontology confers upon our conscious intentions the causal efficacy assigned to them in actual scientific practice, and creates a substance-free interactive dualism. This putative quantum ontology has previously been shown to have impressive explanatory power in both psychology and neuroscience. Here it is used to reconcile the existence of physically efficacious conscious free will with causal anomalies of both the Libet and Einstein-Rosen-Podolsky types.

1. Introduction

We all feel that certain of our conscious thoughts can *cause* our voluntary bodily actions to occur. Our lives, our institutions, and our moral codes are largely based on that intuition. The whole notion of "cause" probably originates in that deep-seated feeling.

The strongest argument against this basic intuition---that our thoughts *cause* our voluntary bodily actions---stems from an experiment performed by Benjamin Libet (1985, 2003). In this experiment a subject is instructed to perform, voluntarily, during a certain time interval, a simple physical action, such as raising a finger. Libet found that a measurable precursor of the physical action, known as the "readiness potential", occurs in the brain about one-third of a second prior to the occurrence of the psychologically described act of willing that action to occur.

This empirical result appears to show, on the face of it, that the conscious act of *willing* must be a *consequence* of this associated brain activity, not the *cause* of it, for, according to the normal idea of cause, nothing can cause a prior happening to occur.

This example is just one instance of a general feature of mind-brain phenomena, namely the fact that conscious experiences always seem to occur after a lot of preparatory work has already been done by the brain. This feature accords with the classical-physics precept of the causal closure of the physical, and it leads plausibly to the conclusion that the felt causal efficacy of our conscious thoughts is an illusion.

One of the most intensely studied aspects of quantum mechanics is the occurrence of correlations in which a "voluntary" choice made at one time appears to affect events that occurred earlier than this choice, or simultaneously with it yet faraway. These correlations were the basis of a famous paper published in 1935 by Albert Einstein and two younger colleagues, Boris Podolsky and Nathan Rosen. The existence of certain puzzles associated with these correlations is called the EPR paradox. These correlations are correctly predicted by quantum mechanics, but they cannot be comprehended within the conception of the physical world postulated by classical mechanics.

In both the Libet and EPR cases the existence of these apparent causal anomalies suggests that what seems to us to be "voluntary" free choices are actually mechanically determined by the physically described aspects of nature, in keeping with the precepts of classical physics. However, the founders of quantum theory were driven, in their search for a rationally coherent understanding of various twentieth century data, to a theory that consistently treats our voluntary choices as "free choices". They are free in the sense that they are not determined by any currently known laws, even though they have, according to the laws of quantum mechanics, specified physical consequences, This article describes how orthodox quantum mechanics reconciles this idea of physically effective voluntary "free choices" with the Libet and EPR data

2. From Classical Mechanics to Orthodox Quantum Mechanics

During the seventeenth century Isaac Newton created the foundations for what developed during the eighteenth and nineteenth centuries into what is now called classical physics, or classical mechanics. Classical mechanics conceives the physical world to be composed of classically conceived particles and classically conceived fields. Classically conceived particles are like miniature planets that move though space under the influence of fields of force generated by the other particles. This entire physical structure develops in time in a way fixed by mechanical laws that *entail the causal closure of the physical*: the whole physically described structure is determined for all time by these mechanical laws---which refer only to these physically described elements themselves---together with initial conditions on these physically described parts.

Around the beginning of the twentieth century it was discovered that this classical-mechanical conception of the physical world was incompatible with the behaviors of large (visible) systems whose activities depended sensitively upon the behaviors of their atomic constituents. The classical conception of physical reality was therefore abandoned by physicists, at the fundamental level, and was replaced by a vastly different conceptual arrangement.

The logical basis of this conceptual change is a curious mathematical change. To pass from a classically conceived physical system to its quantum generalization the *numbers* that described the classically conceived physical properties are replaced by *mathematical actions*, called *operators*.

A principal difference between numbers and mathematical actions/operators is that the order in which one multiplies numbers does not matter---2 times 3 is equal to 3 times 2---but the order in which one applies actions does matter: for two actions A and B, the action of A followed by the action of B, which, for historical reasons, physicists represent as BA is not equal, in general, to AB.

The paradigmatic example is this.

An important number in classical physics is the number x that represents how far some object has been displaced, in some direction, from an initial point x=0. An equally important number is the number p that represents the momentum $p = mv$ of the object, where m is the mass of the object, and v is its velocity in the direction associated with x. In classical physics x and p are *numbers*, and hence $xp - px = 0$, but in the quantum counterpart of the classical system $xp\text{-}px = i\hbar$, where $\hbar$ is a number discovered and measured by Max Planck in 1900, and i is a number that multiplied by itself gives minus one.

This difference between classical mechanics and quantum mechanics might seem to be a mere mathematical technicality, having no deep conceptual import. Indeed, the smallness on the scale of human activities of the effective difference between numbers and the corresponding mathematical actions, might naturally lead one to expect that the *conceptual* changes needed to cope with this mathematical change would be unimportant at the level of human beings and their actions. But this is apparently not the case. The founders of quantum theory, in order to secure a rationally coherent and consistent way of dealing, in a scientifically satisfactory manner, with the technical problems introduced by the replacement of numbers by actions were forced to formulate their theory in terms of *actions*, and in particular the actions of human investigators. Specifically, their theory is formulated in terms of predictions about the observable responses to actions that are chosen *by human agents,* with the intent to probe certain properties of systems described in the mathematical language of quantum mechanics. But this means that the basic physical theory deals *no longer with intrinsic properties of physically described systems*, but, fundamentally, with the interplay between observed and observing systems. And these observing systems are, paradigmatically, conscious human participants. Here the word "conscious" highlights the fact that the theory involves, basically, not solely the physical language of the quantum mathematics, but, equally importantly, also the concepts and language that we human beings use to communicate to our colleagues "what we have done and we have learned". Moreover, the theory involves, in a fundamental way, also the so-called "free choices on the part of the experimenter", which are experienced by experimenters as conscious choices.

Any physical theory, to be relevant to our lives, must link certain mathematical features of the theory to the streams of consciousness of human beings. Quantum theory is built squarely upon the recognition of this fact

To see how this works, consider the mathematical action x discussed above. As already mentioned, this mathematical action x replaces the number x that in classical mechanics specifies where (along a straight line) the (center of an) object is located. The postulated correspondence between the quantum mathematics and experienced perceptions ties the *mathematical action* x *to the empirical probing action that would yield, as its perceived outcome, the number x that would specify the location of the object being probed, insofar as that object has a well defined location.* Similarly, the mathematical action p is tied to a physical probing action that would yield as its perceived outcome the number p that specifies the momentum of the observed object, insofar as that momentum is well defined.

Not every possible mathematical action has a perceptual counterpart. But the basic interpretive assumption in orthodox contemporary physics is that every possible probing action with a perceivable outcome has, in the quantum mathematics, an action counterpart: an associated operator. *Thus an intrinsic mind-matter connection is built directly into the fabric of our basic physical theory*.

This profound difference between contemporary physical theory and the classical physical theories of the eighteenth and nineteenth centuries would appear, prima facie, to be relevant to issues pertaining to the relationship between mind and matter. The earlier theories are approximations to the newer theory, and these approximations systematically exorcize, in a rationally coherent but physically inaccurate way, dynamical connections between mind and matter that the newer theory incorporates.

The connection between mind and matter occurring in the original *pragmatic* formulation of quantum mechanics, which is known as the Copenhagen interpretation, was converted to a connection between mind and brain by an elaboration upon the Copenhagen interpretation developed by the renowned logician and mathematician John von Neumann. This developed form was named “the orthodox interpretation” by von Neumann’s close colleague Eugene Wigner, and it is the starting point of most, if not all, investigations into the nature of the reality that lies behind the pragmatically successful rules of quantum mechanics.

In spite of this seemingly relevant twentieth century development in physics, contemporary neuroscience and philosophy of mind continue to base their quests to understand consciousness on an essentially nineteenth century conceptualization of the human brain, ignoring the facts that the older conception of reality has been known to be false for almost a century, and that, in stark contrast to the nineteenth century conceptualization, contemporary orthodox physics has specified dynamical connections between brains and minds built intrinsically into it.

Planck’s constant is a very tiny number on the scale of human activities. Consequently, the replacement of a classical system by its quantum counterpart turns out to be unimportant for predictions pertaining to the observable properties of physical systems whose behaviors are insensitive to the behaviors of their atomic-sized constituents. But the behaviors of brains are understood in terms the behaviors of the ions flowing into and out of neurons. So it is not clear, a priori, that the behavior of a conscious brain will, in every case, be essentially non-dependent upon how its atomic-sized constituents behave. Indeed, quantum calculations (Stapp, 2004a) pertaining to the release of neurotransmitter molecules into the synaptic clefts separating communicating neurons show that quantum effects are important in principle. According to the principles of contemporary physics the behavior of a living brain must *in principle* be treated as a quantum mechanical system, with classical concepts applied only when justified by special circumstances.

No computations have ever shown that a conscious human brain can be validly treated in the classical approximation. On the other hand, the three-century-old effort to understand the connection between mind and brain within the conceptual framework of materialist classical physics has led to profound conceptual difficulties. These difficulties have provided fertile ground for philosophical disputes that have enlivened the fields of philosophy of mind and neurophilosophy without producing much consensus. But one point of near unanimity is the conclusion that materialism is surely the adequate and appropriate theoretical foundation: for the scientific study of consciousness: that the injection by twentieth century physics of the effects of conscious choices made by observer-participants into the basic dynamics of physical systems can safely be ignored. Still, however, a rationally coherent conceptualization that has *specified* mind-brain dynamical connections---that arise from the basic precepts of empirically valid physics---could conceivably provide a more adequate foundation for the scientific study of the behavior of actually existing mind-brain systems than a nineteenth century approximation that is inadequate in principle for systems whose behaviors depend significantly upon the dynamics of their atomic constituents, and that systematically exorcises the quantum-physics-mandated dynamical effects of conscious choices made by conscious agents.

Over the past few years, I have been engaged in an effort to introduce into the scientific studies of consciousness certain basic results pertaining to the dynamics of the mind-brain system that are entailed by orthodox contemporary physics. Numerous application have been made in the domains of psychology, psychiatry, and neuroscience. (Stapp, 2004a, 2005, 2006a-d); Schwartz, Stapp, and Beauregard, 2005) I shall give here first a brief summary of some of the key elements of this quantum approach, and then use the theory to give a unified treatment of the Libet and the Einstein-Rosen-Podolsky data.

Classical physics is nominally about the *internal properties* of physical systems, but is known to be fundamentally false. It has been replaced by quantum physics, which is about the *interplay* between *observed systems, described in terms of mathematical quantities attached to space-time points (*~ res extensa*), and observing systems, described in terms of elements of streams of consciousness (*~ res cogitans).

Although the various *effects* of a probing action made by a probing system upon a probed system are specified by quantum theory, the *cause* of the probing action is not specified by the theory. There is, therefore, a causal gap! The quantum-theoretic laws determine neither when a probing action will occur, nor which aspects of the observed system will be probed. Niels Bohr emphasizes this key feature of quantum mechanics when he says:

> "The freedom of experimentation, presupposed in classical physics, is of course retained and corresponds to the free choice of experimental arrangement for which the mathematical structure of the quantum mechanical formalism offers the appropriate latitude." (Bohr, 1958, p.73)
>
> "To my mind there is no other alternative than to admit in this field of experience, we are dealing with individual phenomena and that our possibilities of handling the measuring instruments allow us only to make a choice between the different complementary types of phenomena that we want to study. (Bohr, 1958, p. 51)

In practical applications, in both classical and quantum mechanics, physicists treat the human experimenter as an agent who sets up experiments on the basis of his reasons. In neither classical nor quantum theory does anyone actually use the dynamical equations to determine what a real experimenter will actually do. The brain is too complex and too inaccessible to non-disturbing observations at the needed level of accuracy to permit this. In classical physics there is the *presumption* that the physical laws determine *in principle* what an experimenter will do. But this presumption goes far beyond what has been scientifically tested and confirmed. In the more accurate contemporary orthodox quantum theory the conclusion is just the opposite: *in principle the known laws definitely do not determine how the experimenter will act, or even place statistical conditions on these choices*. To fill this lacuna the founders of quantum mechanics brought into the theory certain inputs from conscious human beings, namely their choices of their own actions. This introduction of physically efficacious conscious choices into the physical theory in a fundamental way was the most radical of the breaks with precedent introduced by the founders of quantum theory, and is the one most vigorously opposed by physicists seeking a closer-to-tradition alternative to the Copenhagen and orthodox (von Neumann) approaches. However, none of the proposed alternatives appears to be satisfactory, as yet, even to its supporters. (See Appendix A of Schwartz, et al., and the references cited there, most particularly Stapp 2002, and also Stapp 2006a-d)

Specifically, quantum theory brings into the causal description, in addition to the (sometimes-violated) deterministic continuous evolution in accordance with the quantum generalization of the deterministic classical process of evolution, also *choices of two kinds,* both of which are implemented, or represented, by abrupt "quantum jumps" in the continuous deterministic evolution. One of the two kinds of choices determines the familiar collapse of the wave function (or reduction of the wave packet). It is called by Dirac a "choice on the part of nature", and it is a choice---from among the several alternative possible outcomes of a probing action performed upon an observed/probed system---of *one particular outcome*. These choices "on the part of nature" are "random": they are asserted by the theory to conform to certain statistical conditions. These "choices on the part of nature" are precisely where the randomness enters (irreducibly) into contemporary physics.

But, according to the orthodox precepts, this statistically governed "choice on the part of nature" *must be preceded* by another choice: a choice of which (probing) experiment is to be performed, and when it will be performed. No known laws constrain *this choice of the probing action*, and it is consistently treated in orthodox quantum theory as "a free choice on the part of the experimenter" This "choice on the part of the experimenter" fixes the form of the physically/mathematically described probing action. The representation *within the quantum mathematics* of this probing action is called by von Neumann "Process 1".

The *logical* need for this choice*, which is not specified by any known law,* persists, even when the quantum-mathematically described part of the universe---which in the original Copenhagen interpretation does *not* include either the body or the brain of the observer, or even his or her measuring devices---is expanded (by von Neumann) to include the entire physical universe, *including* the bodies and brains of the observers. The essential point is that the inclusion of the body and brain of the human agent/participant into the quantum-mechanically described universe *still leaves undetermined* the choices made by that human person

This logically needed choice is relegated, in von Neumann's words, to the experimenter's "abstract ego". But no matter what words are used, the fact remains that the inclusion of the body and brain of the observer into the physically described quantum world leaves undetermined the *logically needed choice* of which physical Process1 probing action actually occurs. No known law, statistical or otherwise, specifies which probing action, Process 1 action, actually occurs.

The choosing process, whatever it is, that specifies this choice of the actually occurring Process 1 is called Process 4. Process 2, so-named by von Neumann, is the continuous deterministic evolution via the Schroedinger equation, whereas Process 3 is the choice on the part of nature of which outcome/feedback from the probing action actually occurs, Process 2 reigns only during the intervals *between* the various abrupt Process 1 and Process 3 quantum jumps.

This need for the occurrence of physically efficacious Process 4 choices that are not determined by any known law, statistical or otherwise, constitutes a prima facie breakdown, within orthodox quantum mechanics, of the doctrine of the causal closure of the physical. Quantum theory, as it is taught to physicists in their university courses, is presented as a set of rules that allow scientists to form expectations about the feedbacks they will receive by performing any *one* of many possible probing actions, between which they are free to choose. This practical format is the basis of the conceptual structure of quantum theory.

To prepare the way for the analysis to follow I need to spell out in slightly more detail the structure compactly summarized above.

The conversion of the classically conceived universe to its quantum generalization---obtained by replacing numbers by actions---is called *quantization*. It converts the classical deterministic equation of motion into its quantum counterpart, called "Process 2" by Von Neumann. Like its classical counterpart, this quantum law of evolution is deterministic: left alone, it would determine the quantum state of the universe for all times from its primordial form. The relativistic (quantum field theoretic) form of this law is moreover *local*: the changes in the quantum state associated with any region are determined by the properties associated with very nearby regions, and no influence propagates faster than the speed of light.

This Process 2 evolution, by itself, is dynamically insufficient. Given some initial conditions it produces at a later time not the mathematical counterpart of *one single perceptual probing action*, but rather the counterparts of a *continuous smear* of alternative possible probing actions. Orthodox quantum theory resolves this difficulty by supplementing the Process 2 evolution by certain abrupt changes, which von Neumann calls "Process 1 interventions". Each such mathematical intervention is tied by the quantum laws to a particular perceivable probing action performed upon the observed system by an observing system external to it.

Neither the property of the observed system that is probed by this intervention, nor the time when this probing action occurs, is fixed by the mechanical Process 2. These two features are considered to be fixed by the observing system. This assignment of responsibility, or of causal origin, accords with the fact that in actual scientific practice it is the human experimenter that selects, by conscious choice, which particular probing action will be performed upon the system he or she is observing, and when that probing action will be performed. Of course, an agent's conscious choices are not independent of what is going on in his brain, but *orthodox contemporary physics does not determine* how the psychic and physical components of reality combine to *cause* the Process 1 events to be what they turn out to be.

The *effect* of the Process 1 intervention upon the observed system *is* specified by the quantum laws. This intervention selects from the smear of possible probing actions some particular one. The effect of this singled-out probing action upon the mathematically described state of the observed system is this: it separates this state into a set of disjoint (i.e., non-overlapping) components in a way such that: (1), the statistical weights assigned by the theory to these individual components adds to unity; and (2), each component corresponds to a *phenomenologically distinct* outcome of that probing action.

After this Process 1 separation has been made, nature picks out, and saves, *one* of the possible psychophysical outcomes of the chosen probing action, and eradicates the rest. *Nature's* selection of outcomes---called Process 3 in my terminology---is asserted by the theory to respect the statistical weights assigned to the alternative possible outcomes. The quantum mathematical structure becomes tied in this way to phenomenology, and the theory generates practical rules that allow statistical predictions pertaining to experiences to be deduced from the postulated mathematical structure.

This injection of human volitional choices into the physical dynamics *at a basic level* is completely contrary to the precepts of classical physics. But this change accommodates the fact that we human beings do in fact inject our conscious intentions into the physically described world whenever we act intentionally. Accepting quantum mechanics opens the door to the possibility of a more detailed, *and more useful,* putative understanding of this effect of conscious intent than classical mechanics can provide.

3. The Libet Causal Anomalies

In the Libet experiment the initial intentional act is to choose willfully to perform, at some future time within, say within the next minute, the act of raising a finger. We often make such resolves to act in some specified way at some future time, and these commitments are often met with great precision. However, in the Libet case the resolve is rather imprecise as regards the exact time of the specified action. It is doubtful that any person, informed even by a multitude of probing devices about the state of the subject's brain at the beginning of the specified interval, could predict with good accuracy just when the choice to move the finger will occur. And even if every neurophysiological-level feature of the brain were given at the outset, it is still questionable whether, even in a world that obeyed the deterministic laws of classical physics, this macroscopic data would fix the time at which the conscious choice occurs. There is just too much latitude for initially small-scale variations to develop over the course of time into significant macroscopic effects. Even within deterministic classical physics the best one could do with actual macroscopic data would be to make a statistical model based on that data and the known general properties of the brain.

In the case of the dynamics of a warm wet living human brain, interacting with its environment, almost all quantum interference effects *connecting appreciably different locations* will (almost certainly) be washed out, and the quantum model will become similar to a classical *statistical* model that features a collection of parallel classically conceived worlds, each with some statistical weight. However, in the classical case one can imagine that exactly one of the statistically weighted alternative classically conceived possibilities is the "real" one, and that the statistical smearing represents a mere lack of knowledge as to which of the weighted possibilities represents the "actual real world".

This "lack of knowledge" interpretation cannot be carried over to quantum theory. However, to a good approximation, the various weighted classically conceived worlds of classical statistical theory can be understood to represent *simultaneously existing potentialities*, some subset of which will eventually be selected by some Process 1 probing event. This Process 1 action will be followed by a Process 3 choice (on the part of nature) that specifies which of the alternative possible outcomes of the chosen probing action actually occurs. *All potentialities that do not lead to the outcome that actually occurs are eradicated by these collapse or reduction events, leaving only those that lead to the psychophysical event that actually does occur.*

In the Libet experiment, the mind-brain "set" fixed by the initial conscious intention to raise the finger within the next minute should cause the quantum mechanically described brain to generate classically describable potentialities corresponding to the various alternative times at which the specified conscious act could occur. Thus the following scenario is compatible with quantum mechanics, and is suggested by it.

The initial intent (to raise the finger within the next minute) will lead to the production of a collection of parallel potentialities, each corresponding to a possible time at which the readiness potential can start its build up. Shortly after some of the classically described potentialities have developed to the point of specifying a certain possible perceivable probing action the question will pop into the stream of consciousness: "Shall I perform this action?" If the answer is 'No', as it is likely to be right at the beginning, then the potentialities *leading up to the performance of that action at that time* will be eradicated. A short time later a similar Process 1 question will be posed. The outcome is again likely to be 'No', and the batch of potentialities leading to the 'Yes' option will again be erased. Eventually, in accordance with the statistical rules, a 'Yes' outcome will be selected by nature, and the set of potentialities leading to the 'No' outcome will be wiped out. Only the (essentially classically described) potentialities *leading to* this 'Yes' outcome will remain.

The "Yes" event is a psychophysical event that is felt or experienced as the feeling or knowledge "I shall now raise my finger", and it is represented in the physically described world as the actualization, at that moment, of the neurological activity that constitutes the template for the action of raising the finger. (This template is a neural/brain activity that, if held in place for a sufficiently long interval, will tend to cause the finger to rise.) All brain activities---*which have the ontological character of potentialities*---that are incompatible with this intent are *eliminated by this event* from the quantum mechanical state of the brain. Hence they are eliminated from the statistical mixture of classically described states that approximately represents this quantum state.

Now suppose there is in place some measuring device that can, in the approximately correct classical description of what is (possibly) going on, detect the time at which the readiness potential starts its build up. This time of the inception of the build up is long (one-third of a second) before the psychophysical event that will, *only later,* actualize this particular classically described world. Now suppose, furthermore, that the classically described measuring device activates a classically described timer that records the time of the beginning of the build up of the readiness potential. This classically described *record* of the time of the start of the build up of the readiness potential will continue to exist along side the increasing readiness potential. When some person, at some later time, after the occurrence of the psychophysical event that determines which of the classically described worlds survives---and hence that determines also the time at which the build-up of the readiness potential began---reads the timer he will find out that the start of the build up of the readiness potential occurred *before the occurrence of the psychophysical event that selected the classical world that specifies the time when that build up began.*

The key point here is that the *record* of the time of the start of the build up of the readiness potential is *a causal off shoot* of this build up, and this record will be actualized along with the actualization of the potentiality *represented (to a good approximation) by* the classically described process that the actualization event selects. Thus the recorded time of the beginning of the build up of the readiness potential will be earlier than the time of the event that actually determined (according to this quantum ontology) the time of the beginning of this build up: the recorded time of the beginning of the build up will be fixed by an event that occurs only later.

Such seeming causal anomalies have been a prime point of attack on orthodox quantum theory, and they continue to fascinate physicists even today, under the names “quantum nonlocality”, or “Bell’s theorem”, or “EPR paradox.” Although this quantum ontological way of understanding the quantum correlation tends to upset people accustomed to thinking about the world in classical mechanical terms, no logical inconsistency or conflict with empirical data has ever been established. One can be quite confident in accepting that all of the known empirical evidence is compatible with this non-classical but logically consistent “quantum ontological” conception of how the world works.

On the other hand, one can certainly adhere, alternatively, to the *pragmatic* point of view, which holds that, even though this quantum ontology accords with all of the empirically verified relationships between human experiences, and seems to provide a coherent putative “understanding” of what is going on, this success by no means implies that this understanding is veridical. For one can express the empirical predictions in compact ways that avoid any commitment concerning what is “really happening”. Thus many---and probably most---quantum physicists hold that, as scientists, the pragmatic option is all they need to commit to. On the other hand, for those who seek something more than merely "a set of rules that work" the quantum ontological model is a viable (i.e., not yet disproven) and logically coherent conception of the way that Nature actually works. The same cannot be said of local deterministic materialism.

Human agents play a very special role in this quantum ontology. This feature is a hold-over from the pragmatic stance of the original Copenhagen formulation of the theory, which was concerned principally with establishing a rationally coherent basis for practical applications. However, von Neumann's analysis shows that there is no empirical evidence that *every* occurring collapse event is associated with an event in a human stream of consciousness. It is certainly more plausible, from a scientific perspective, to assume that there are similar events associated with other biological organisms, and there is no empirical evidence that confutes that position. Indeed, von Neumann's analysis reveals, more generally, that collapse events that act *macroscopically* on physical systems that are interacting strongly with their environments would be virtually impossible to detect. There is presently no evidence that rules out the possibility that enormous numbers of macroscopic collapse events are occurring all the time in large systems that are strongly connected to their environments. Hence the special role originally assigned to human beings is no part of the general quantum ontological model being described here.

The main cause of reservations about the actual truth of this quantum ontology is that it entails faster-than-light transfer of information. These faster-than-light issues are essentially those that arise in the much-discussed EPR paradox.

4. The Einstein-Podolsky-Rosen Causal Anomalies

Albert Einstein, Boris Podolsky and Nathan Rosen, published in 1935 what is perhaps the most discussed scientific paper of the twentieth century. Entitled "*Can quantum mechanical description of physical reality be considered complete?*" the paper argues that Copenhagen quantum theory does not give a complete description of physical reality. The argument depends on a specific way of identifying what is meant by "physical reality". This identification depends on an assumption about the absence of influences that act backward in time or faster than the speed of light. Niels Bohr (1935) wrote a rebuttal that essentially admitted that the strong notion of no-faster-than-light influence used in classical-physics does indeed fail in quantum theory, but claimed that an adequate replacement holds within the epistemological framework of quantum mechanics.

The Einstein-Podolsky-Rosen argument is based on an examination of the predictions of quantum theory pertaining to certain correlations between *macroscopic* observable events that occur at essentially the same time in laboratories that lie far apart

A simple classical example of a correlation between events occurring at essentially the same time in far-apart laboratories is this. Suppose one has a pair of balls, one red, the other green. Suppose one loads them into two rifles, and fires them in opposite directions into two far-apart laboratories, in which the balls will be caught and examined at essentially the same time. The colors found in the two regions will obviously be correlated: if red is found in one lab then green will be found in the other, and vice versa. There is nothing strange or peculiar about a correlation of this kind.

The simplest quantum example is similar, and is again not in itself a problem. We can set up a *certain experimental arrangement of the macroscopic preparing and measuring devices* that will produce a situation analogous to the one with the two colored balls. Quantum mechanics predicts, and empirical evidence confirms, that, under these *macroscopically specified* experimental conditions, if a red light flashes on the detector in one laboratory, then a green light will flash at essentially the same time on the detector in the other laboratory, and vice versa.

Einstein and his colleagues (henceforth EPR) considered a slightly more complex situation in which there are two alternative possible settings of the measuring device in the first lab and two alternative possible settings of the device in the second lab. If the *first* setting is chosen in *both* labs then, as before, green in either lab entails red in the other, and vice versa. Moreover, if the *second* setting is chosen in *both* labs then, as before, green in either lab entails red in the other, and vice versa

A basic feature of quantum theory is this: the theory is mathematically incompatible with the idea that there exists *both* a property P1 that fixes which outcome will occur if the measurement in, say, the second lab specified by the *first* possible setting of the device in that (second) lab is performed, *and also, simultaneously,* a property P2 that fixes which outcome will occur if the measurement in the second lab specified by the *second* possible setting of the device in that (second) lab is performed. Quantum theory regards two such properties, P1 and P2, as *complementary* properties that cannot both exist simultaneously.

EPR devised an argument that seemed to show that these two properties P1 and P2 do exist simultaneously. Their argument produced consternation in Copenhagen. Bohr's close colleague, Leon Rosenfeld (1967) described the situation as follows:

> This onslaught came down upon us like a bolt from the blue. Its effect on Bohr was remarkable. We were then in the midst of groping attempts at exploring … [another problem] …. A new worry could not come at a less propitious time. Yet as soon as Bohr had heard my report of Einstein's argument, everything else was abandoned: we had to clear up such a misunderstanding at once. We should reply by taking up the same example and showing the right way to speak about it. Bohr immediately started dictating to me the outline of such a reply. Very soon, however, he became hesitant: "No, this will not do, we must try all over again … we must make it quite clear…" So it went on for a while with growing wonder at the unexpected subtlety of the argument. … Eventually he broke off with the familiar remark that he "must sleep on it." The next morning he at once took up the dictation again, … the real work now began in earnest: day after day, week after week, the whole argument was patiently scrutinized … .

What is the argument that set off this huge commotion, which reverberates even to this day?

Einstein and his colleagues introduced the following “criterion of physical reality”:

> If, without in any way disturbing a system, we can predict with certainty (i.e., with probability equal to unity) a physical property of a system then there exists an element of physical reality corresponding to that property.

This criterion seems completely reasonable, and completely in line with the Copenhagen philosophy, which is built upon the idea of predictions of properties of systems as revealed by the observed outcomes of experiments performed upon those systems.

In the experimental situation just mentioned the setting of each device can be chosen and fixed *just before* the outcome at that device appears. The distance between the two labs can then be made so large that there is no time (according to the claim of the theory of relativity that *nothing* can travel faster than the speed of light) for *a choice of setting* in either lab to have any effect at all on *the faraway outcome*, red or green.

However, the experimenter in the first lab *can predict with certainty* the *property P1 that is measured by using the first setting in the (faraway) second lab.* He can do this simply by choosing the *first setting in his own (first) lab* and observing the outcome, red or green, and then inferring that P1 must be, respectively, green or red. The assumed---by EPR---impossibility of any faster-than-light or backward-in-time influence entails that this *action and act of observation in the first lab* cannot disturb in any way this property P1 measurable in the second lab. Thus, according to the EPR criterion, there is an element of physical reality P1 corresponding to the property that is measured in the second lab when one uses there the *first* setting.

By choosing the *second* setting in the first lab one finds that a property P2 corresponding to the *second setting* in the second lab is, likewise, an element of physical reality. But---for inescapable mathematical reasons---quantum theory cannot accommodate the simultaneous existence of these two elements, P1 and P2, of physical reality. Hence, as a description of physical reality, quantum theory must, according to EPR, be incomplete

EPR finish off their argument with the following crucial remark:

> One could object to this conclusion on the grounds that our criterion or reality is not sufficiently restrictive. Indeed, one would not arrive at our conclusion if one insisted that two or more physical quantities can be regarded as simultaneous elements of reality only when they can be simultaneously measured or predicted. On this point of view, since either one or the other, but not both simultaneously of the quantities P and Q can be predicted they are not simultaneously real. This makes the reality of P and Q depend upon the process of measurement carried out on the first system, which does not disturb the second system in any way. No reasonable definition of reality could be expected to permit this.
>
> [EPR’s P and Q are essentially equivalent to our P1 and P2]

Bohr accepts that the orthodox principles of quantum theory demand that P and Q cannot, within that theory, both be assigned well defined values. How does he reconcile this fact with the EPR argument that both are elements or physical reality?

The essence of Bohr's reply (Bohr, 1935) is the following passage:

> From our point of view we now see that the wording of the above-mentioned criterion of physical reality proposed by Einstein, Podolsky, and Rosen contains an ambiguity as regards the meaning of the expression "without in any way disturbing the system." Of course there is in a case like that just considered no question of a mechanical disturbance of the system under investigation during the last critical stage of the measuring procedure. But even at this stage there is essentially the question of *an influence on the very conditions which describe the possible types of predictions regarding the future behaviour of the system.* (Bohr's italics.) Since these conditions constitute an inherent element of any phenomenon to which the term "physical reality" can be properly attached, we see that the argumentation of the above-named authors does not justify their conclusion that quantum-mechanical description is essentially incomplete.

If Bohr's argument strikes you as obscure, then you are not alone. Many philosophers and physicists have judged Bohr's reply to be insufficient, and have concluded that Einstein won the debate. Bohr himself says, in his contribution to the Einstein volume (Einstein, 1951, p. 234), "Reading these passages, I am deeply aware of the inefficiency of expression which must have made it very difficult to appreciate the trend of the argumentation…."

That is an accurate statement. Yet his later arguments do not seem to help.

One feature of Bohr's answer does come across clearly: his reply rejects, *at some level*, Einstein's idea of "without in any way disturbing the system": Bohr rejects, at some level, Einstein's assumption that the freely chosen measurement process performed in the nearby lab *does not disturb in any way* the system in the faraway lab, even though any such disturbance would have to act essentially instantaneously. That is, in order to rationally counter the Einstein argument Bohr found himself forced to reject Einstein's principle that *all* causal actions act only forward in time, and no faster than the speed of light. If that principle fails, the EPR argument collapses.

Bohr's point, in essence, is that once the experimenter in the first lab chooses to do one of the two possible measurements in his lab, for example the one specified by the first (resp. second) setting in his own lab, he loses the capacity to make any prediction about the outcome of a measurement in the other lab associated with the second (resp. first) setting in that faraway lab. Thus the experimenter's choice of what to do here has changed *what he can know* about events in the faraway region. In an essentially epistemological theory in which the basic reality is "our knowledge", a *reality* associated with the faraway lab can therefore *be said* to depend upon a one's choice made here about what one will freely choose to do here. But then the EPR claim that no reality "there" can depend upon what one can freely choose to do "here" fails: the EPR argument goes down the drain.

Of course, an epistemologically based conception of reality goes against Einstein's more traditional idea of reality. But this issue of the need of the basic physical theory to deal with non-epistemologically-based realities is the core issue in the Bohr-Einstein dispute. Hence, Einstein cannot simply assert, without in some way begging the central question, that "reality" must be defined non-epistemologically.

Bohr's argumentation is basically philosophical, and about what we can know. It dodges the ontological issues usually associated with the phrase "physical reality", which is normally *contrasted* to what we know, or can know. But the von Neumann-based quantum ontology described above explains the workings of this "action at a distance" in "ontological" terms. This ontology incorporates Heisenberg's idea of "potentia" as an objective tendency for a physically describable event to occur in association with an increment in human knowledge. This ontology that is based not on *substances* but rather on psychophysical *events* and mathematically described "*objective tendencies*" for such events to occur. These tendencies are non-substantive because they can change abruptly whenever a new psychophysical event occurs, perhaps faraway. It is, basically, the acceptance of such "*tendencies* as *objective realities"* that differentiates this Heisenberg-type quantum ontology from substance-based ontologies.

The quantum ontological explanation of the EPR-type correlations is similar to the explanation of the Libet back action. In the EPR case the actualization in one region of some particular probing action and its outcome actualizes also the particular causal chain that leads up to that outcome, *along with its causal off shoots*, and it eliminates the *potentialities* that would have produced the possible outcomes that were not actualized. But then a conscious choice of probing action made at one time and place can have ontological consequences in faraway regions. These faraway consequences are effects of *causal off shoots of possible processes that are actualized by events in the nearby region that depend on choices freely made in the nearby region.*

These words are more than verbal hand waving. They are descriptions in ordinary words of exactly what the von Neumann mathematical representation of the evolving state is doing. Insofar as one accepts the idea that the reality is represented by the mathematics, and that our words and concepts should conform to what the mathematics is saying, this quantum ontology follows. It is an accurate description of what the quantum mathematics is saying.

This ontology accords with the orthodox quantum principle that the properties P1 and P2, discussed above, do not exist simultaneously, and that the existence or nonexistence of such a property in one region can depend upon what a faraway experimenter does in a region that is space-like separated from the first. That is, this ontological conceptualization is in accord with the orthodox quantum principles, and it rejects, in agreement with Bohr's answer to EPR, the strong version of the principle of no faster-than-light effect *of any kind*. Bohr's rejection was, as already mentioned, essentially epistemological, and the quantum ontology translates this into a non-classical non-substantive ontological conceptualization that does bring into the dynamics effects of our "free" choices of how we will act.

One essential point needs to be emphasized. Von Neumann's formulation of quantum theory, which provides the mathematical foundation for this ontology, was first published in 1932, and it is non-relativistic. A state of the universe is given for each "instant of time". However, this formalism was generalized by Tomonaga (1946) and by Schwinger (1951) around the middle of the twentieth century to *relativistic quantum field theory*, with the quantum states now defined not on fixed-time surfaces but on space-like surfaces. (Every point of a fixed-time surface lies at the same time, whereas points on a space-like surface can lie at different times, but every point of a space-like surface is separated by a space-like interval from every other point on that surface.)

In this relativistic generalization, a Process 1 event, freely chosen and acting on a local (nearby) portion of a space-like surface, followed by some local (nearby) Process 3 outcome can "instantly" affect the part of the state associated with a distant (faraway) portion of that space-like surface. And this "faraway" effect can depend upon which Process 1 event was locally chosen. Thus Einstein's demand that such choices of probing actions can have *no faster-than-light influence of any kind* is violated, in accord with Bohr's denial of the validity of that condition. However, the relativistic formulation *does satisfy* the basic requirement of the theory of relativity that no "signal" can be transmitted faster than light. (A *signal* is a message such that the decipherable content received is influenced by the sender.) Thus in the robust practical sense of communicating what one knows (here) to distant receivers, there are no faster-than-light actions, even though the (Tomonaga-Schwinger) quantum ontology does explicitly exhibit faster-than-light transfers to faraway regions of information that is influenced by nearby free choices.. The reason that this explicit faster-than-light transfer of information cannot carry a message intended by the local experimenter is that the faraway effects of the nearby choice depends *jointly* upon the experimenter's choice of the local experiment and nature's choice of the local outcome in such a way that if the faraway receiver knows nothing about nature's local (nearby) choice then he cannot acquire from his observations any information about the experimenter's local (nearby) choice. This result is a direct consequence of the quantum rules.

The relativistic (Tomonaga-Schwinger) von Neumann ontology satisfies the demands of the theory of relativity, yet explicitly exhibits the sort of faster-than light effects alluded to in Bohr's answer to EPR. This rationally coherent conception of nature resolves the mysteries of the seeming causal anomalies by setting forth a new "quantum-theoretic" way of understanding nature; an understanding based not on substances but on psychophysical events and objective tendencies for such events to occur.

The fact that this particular orthodox ontology involves faster-than-light effects does not imply that *no* rationally coherent theory can agree with the quantum predictions unless it allows transfer of information about a free choice made in one region to a space-like separated region. But that strong result can be proved.

Certain theories entail the validity of certain statements of the form:

If experiment 1 is performed and the outcome is A, then if, instead, experiment 2 had been performed the outcome would necessarily be B.

For example, according to classical physics, if we shoot a charged particle into a region with, say, uniform magnetic field H and it follows a semi circle of radius R then if we had chosen magnetic field 2H, with every other relevant thing unchanged, then the particle would have followed a semi-circle of radius R/2.

To establish the unavoidable need in any adequate theory of nature for some sort of faster-than-light transfer we may consider an experiment of the kind first investigated by Julian Hardy. As in the EPR case, there are two space-time regions situated so that nothing can get from either region to the other one without traveling either faster than light or backward in time. In each region either one or the other of two alternative possible probing actions can be chosen and performed. And, for each performed experiment, one or the other of two alternative possible outcomes of that experiment will appear in the region in which that measurement is performed.

Let one of the two regions be called R and the other be called L, and let the space-time region R lie *later* than the space-time region L (in some specified coordinate frame.) The first needed assumption is this:

> The choices of which of two possible experiments will be performed in regions R and L *can be treated* as independent free variables.

This does not mean that in the total scheme of things each of these two choices is undetermined until it actually occurs, but only that the choice of which experiment to perform can be fixed in so many alternative possible ways by systems so disconnected, prior to the probing action, from the system being probed, that the choice of which probing action is performed *can be treated* as a free variable in the context of the analysis of this experiment. This free choice assumption is endorsed by Bohr, and is used by EPR.

The second assumption is this:

> No matter which experiment is chosen and performed in the earlier region L, whatever outcome *appears and is recorded there* is independent of which probing action will be chosen and performed later in the faraway region R.

These two assumptions, along with the assumed validity of four simple predictions of quantum theory for a Hardy-type experiment allow one to *prove* some interesting properties of the following statement, which I have named SR, because it is a statement that refers to possible happenings in region R:

> SR:: If the first of the two alternative possible probing actions in region R gives the first of the two possible outcomes, then the second of the two alternative possible

probing actions in region R, if it had been performed instead of the first one, would necessarily have given the first possible outcome of that second probing action.

This statement does not involve two co-existing incompatible properties: the two incompatible properties in R exist only under incompatible conditions in R

Statement SR is *logically entailed by the two assumptions described above and the validity of four predictions of quantum theory* to be true or false according to whether the experimenter in region L chooses to perform in L one or the other of the two alternative possible actions available to him or her. (Stapp, 2004b)

The conditions that logically determine whether this statement SR is true or false are conditions on outcomes appearing in region R under the alternative possible conditions that can be freely chosen in that region R. But this statement is required by the laws of quantum mechanics to be true or false according to which choice is freely made by the experimenter in region L, which is space-like separated from region R. This demand cannot be met by a theory that allows no information about the free choice made in L to get to the region R.

A rationally coherent understanding of natural phenomena that allows our choices of which experiments we perform to be treated as free variables is logically possible, but any such theory that strictly enforces the principle of no faster-than-light or backward in time transfer of information appears to be excluded by this argument, which thereby removes an important barrier to the acceptance of the quantum ontology described above.

5. Application to Libet

Numerous applications of this quantum ontology to the understanding of phenomena in psychology, psychiatry, and neuroscience related to the connection of mind to brain have been described in Schwartz (2005). The central idea is to begin to fill the lacuna in the causal structure associated with Process 4---the process of choosing *which* Process 1 will occur, and *when* it will occur---by distinguishing two kinds of Process 4 choices: passive choices and active choices. The passive choices are entailed by brain activity alone: for these passive choices the Process 1 action occurs when an associated threshold in brain activity is reached. The expression of this physically described threshold remains to be specified. (cf. Stapp, 1999) Once this initial psycho-physical event occurs, and the follow-up Process 3 outcome has produced a 'Yes' response, there can be a felt evaluation. The key assumption is that if this felt evaluation is sufficiently positive then there may be an *active* effort to attend to this idea, which, if sufficiently strong, will produce an almost immediate repeat of the original psychophysical event associated with Process 1. If the repetitions are sufficiently rapid then a well-known quantum effect, the quantum Zeno effect, will cause a long string of essential identical Process 1-Process 3 pairs to occur. This rapid sequence of events will, by virtue of the known quantum rules, tend to hold in place the associated template for action, and this will tend to cause the intended action to occur. Thus conscious intentions motivated by felt valuations become injected into the brain dynamics in a way that tends to cause consciously intended actions to occur. (See Stapp 2004a, Chapt. 12 for the mathematical details.)

This conception of what is going on is in close accord with William James's assertions (James, 1892)

> I have spoken as if our attention were wholly determined by neural conditions. I believe that the array of things we can attend to is so determined. No object can catch our attention except by the neural machinery. But the amount of the attention which an object receives after it has caught our attention is another question. It often takes effort to keep mind upon it. We feel that we can make more or less of the effort as we choose. If this feeling be not deceptive, if our effort be a spiritual force, and an indeterminate one, then of course it contributes coequally with the cerebral conditions to the result. Though it *introduce* no new idea, it will deepen and prolong the stay in consciousness of innumerable ideas which else would fade more quickly away. The delay thus gained might not be more than a second in duration---but that second may be critical; for in the rising and falling considerations in the mind, where two associated systems of them are nearly in equilibrium it is often a matter of but a second more or less of attention at the outset, whether one system shall gain force to occupy the field and develop itself and exclude the other, or be excluded itself by the other. When developed it may make us act, and that act may seal our doom. When we come to the chapter on the Will we shall see that the whole drama of the voluntary life hinges on the attention, slightly more or slightly less, which rival motor ideas may receive. ...
>
> Consent to the idea's undivided presence, this is efforts sole achievement

This understanding is in line also with James's assertion (James, 1911):

> your acquaintance with reality grows literally by buds or drops of perception. Intellectually and on reflection you can divide them into components, but as immediately given they come totally or not at all.

Turning to the Libet situation, we see that there is an important difference between it and the EPR situation. In the Libet case the initial action that initiates the agent's later actions, namely the agent's commitment to raise the finger sometime during the next minute, occurs *before* the development of the causal offshoot, and it generates the chain of events associated with both the creation of the causal offshoots (namely the creation of the *records* of the beginnings of the various parallel build-ups of the readiness potential) and also the subsequent conscious probing actions, one of which will eventually lead to the actualization of *one* of these records. This causal linkage breaks, in the Libet case, the control of the *active* conscious choice (to raise the finger now) upon the causal off shoot (the record). In the Libet case these *active* conscious choices act only to hold the template for action in place long enough to cause the finger to rise, or, by failing to so act, to effectively *veto* that physical action. Thus the *active* conscious choices do not influence the causal off shoots in the efficacious way that they do in the EPR case. They act only either to consent to the process of raising the finger, caused by the initial commitment to do so and nature's subsequent "Yes", or to veto this physical action by refusing to initiate the repetitions needed to produce the action. (See e.g, Schwartz et. al.) However, in the generation of correlations between two phenomena occurring different regions, the key role of an actualization of a potentiality having a causal off shoot is the same in both the Libet and EPR cases, as is the explanation of the capacity of a person's conscious choices, unconstrained by any yet-known laws, to influence his physical actions.

6. Conclusion

The quantum mechanical understanding of the mind-brain dynamical system explained and defended in Schwartz (2005), and further elaborated in Stapp (2005) and Stapp (2006), accommodates, and putatively explains, the ability of our conscious intentions to influence our physical behavior. This theory covers in a natural way also the Libet data. It reconciles Libet's empirical findings with the capacity of our conscious intentions to influence our actions, without these intentions being themselves determined by the physically described aspects of the theory. This separation is achieved by exploiting a causal gap in the mathematically expressed laws of quantum mechanics. This gap is filled in actual scientific practice by invoking the conscious intentions of the human participants. This practical and intuitively felt role of conscious intentions is elevated, within the proposed quantum ontology, to the status of an ontological reality coherently and consistently integrated into quantum laws.

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A2. Quest for Consciousness.

This Appendix is another article prepared for publication.

The Quest for Consciousness: A Quantum Neurobiological Approach.

Christof Koch has recently written an extremely accessible book, *The Quest for Consciousness: a Neurobiological Approach*. It summarizes in a clear way the main known biological facts that seem particularly pertinent to the mind-brain problem, along with an attempt to understand these facts within the framework that he has been developing in collaboration with Francis Crick. This theoretical framework, although only one of many being pursued at present, is probably as close to main-line neurobiology as any. This article contrasts Koch's way of accounting for certain time-related psycho-neurobiological data with a physics-based understanding of these data.

By a physics-based understanding I mean an understanding based on the fundamental principles of physics, as they are understood today by physicists. This understanding differs profoundly from the one that prevailed at the end of the nineteenth century. During the first part of the twentieth century it became clear that the earlier approach was conceptually unable to account for the results of the observations that we make upon systems whose behaviors depend sensitively on the motions of their atomic constituents. Physicists, lead by Niels Bohr, Werner Heisenberg, and Wolfgang Pauli, erected the new and empirically successful physical theory based not on the idea of evolving material substances, but rather upon the idea of a sequence of abrupt events. Each of these events is *psychophysical* in the sense that it has, on the one hand, certain aspects that are described in the ordinary language that, in Bohr's words, we use to communicate to others "what we have done and what we have learned", and, on the other hand, other aspects that are described in the mathematical language of physics. These psychophysical events link certain physically described aspects of the systems we observe to events in our minds. These mind-matter connections were subsequently converted by John von Neumann to connections between the minds and the brains of human observer-participants. This introduction, at the level of the basic physics, of events that relate physical descriptions of our brains to events in our streams of consciousness has led many physics who are interested basic ontological issues to the conclusion that twentieth century physics may provide the a more adequate foundation for understanding the connection between our brains and our minds than its nineteenth century predecessor. The latter is, strictly speaking, an approximation to the former that systematically leaves out the physical effects of our conscious choices that twentieth-century physics explicitly brought in.

This possibility that the inclusion of the mind-brain connections specified by basic physical principles might offer a more rationally coherent and useful conception of the connection between our conscious thoughts and their neural correlates than the prevailing classical-physics-based ideas in neuroscience can allow has recently been explored in some detail. (Schwartz, Stapp, and Beauregard 2005, Stapp 2004, 2005). The encouraging findings will not be reviewed here. However, readers of this article do need a sufficient understanding of what is meant here by "orthodox contemporary quantum theory of the mind-brain connection". Hence, before describing the contrasts between Koch's explanations of the psychobiological data and the physics-based account, a brief description needs to be given of the significant contrasts between these two alternative theoretical frameworks.

Physics-based approach to the connection between mind and brain.

It is by now widely appreciated that the materialist-deterministic conception of nature that prevailed during the eighteenth and nineteen centuries fails to account for the macroscopic properties of systems whose behaviors depend sensitively on the behaviors of their atomic-sized constituents. That earlier theory was replaced during the first half of the twentieth century by quantum theory. The basic mathematical change was to replace the *numbers* of the older theory by *operators.* The effect of this replacement is to change the theory from one putatively about intrinsic observer-independent properties of physical systems to one explicitly about the observed feedbacks from actions performed upon an observed system by an observing system. Observing systems that stand apart from observed physical systems, but that act upon them in chosen ways, are thus brought crucially into the dynamics of the combined observer-observed system.

The older theory, classical mechanics, has *one* single dynamical process, the continuous evolution of the physical universe in accordance with Newton's laws, or some classical-type generalization of them. In contrast, the new theory, quantum theory, is built around a sequence of discrete events that is governed by four processes. Each such event is, from an ontological perspective, simultaneously: (1), an actualization of certain mathematically characterized potentialities created by prior events; (2) a creation of potentialities for future events; and (3), an experiential event that constitutes an increment in knowledge.

One of the four processes governing the flow of these events is called Process 1 by von Neumann. It is *a mathematically characterized abrupt action of an observing system upon an* *observed system*. This action has the effect of specifying a particular question about the observed system. Another process, called Process 2 by von Neumann, is a continuous deterministic process. It is the quantum analog of the single deterministic process of classical physics, but it acts only during the intervals between successive abrupt events. The third process is the abrupt event of answering the question specified by Process 1. It is called by Dirac a "choice of the part of nature". It is *random*: it conforms to specified statistical conditions. This "Process 3" is where the famous "random element" enters into quantum mechanics. The fourth process is called Process 4. This action is what Niels Bohr calls a "free choice on the part of the experimenter." This choice specifies which particular probing action---taken from among a host of allowed possibilities---will be instigated by the experimenter. This choice is not constrained or limited by any currently known law, statistical or otherwise, and is treated, in actual scientific practice, as the conscious choice of a human agent. Because this choice is not fixed by any *known* laws it is, in this very specific sense, a "free choice".

Quantum mechanics is, in this way, explicitly about observations and their outcomes, both of which are represented by abrupt events that suddenly change the physically described properties of the observed system in a way concordant with increments of knowledge of the observer. In the von Neumann formulation the directly observed system becomes the brain of the observer, and the mind-matter connections are converted to mind-brain connections. This re-conceptualization of physics is radically different from the earlier classical conceptualization, which effectively leaves out all experiential realities. The quantum framework is more *complete* than the earlier classical framework, because it incorporates descriptions of both our physically described brains and also associated experiential realities, and it specifies the form of a dynamical connection between them. Both of these aspects of our understanding of nature are essential components of science, and quantum theory is expressly designed to bring usefully into science the fact that "in the great drama of existence we ourselves are both actors and spectators." (Bohr, 1963, p. 15: 1958, p. 81)

An important characteristic of this quantum conceptualization is that the substantive-matter-like aspects, have dropped out. The theory is about: (1) abrupt *events*, each of which is tied to an experiential increment in knowledge; and (2) *potentialities* for such events to occur. Events are not substances, which, by definition, endure. And the potentialities have an "idea-like" character because they are like an "imagined" idea of what the future events *might* be, and they change abruptly when a new event occurs. Thus neither the events nor the potentialities have the ontological character the substantive matter of classical physics. Yet the predictions of quantum mechanics encompass all of the known successes of classical mechanics.

A second important feature of this quantum ontology is that the conscious "free choices" ---which are not determined by any known law---can influence the course of the psychophysical events. The principle of the "causal closure of the physical" is therefore not enforced in orthodox quantum theory, not only because of the entry, via Process 3, of random elements, but also, and more importantly in the present context, because of the entry of physically effective Process 4 conscious free choices. These latter choices can influence the *objective potentialities* for future actual events, and thereby affect also what actually happens.

A third important point is this. By virtue of the quantum rules themselves, a *conscious intent* to perform either a physical action or a mental action (say to recall something or to focus one's attention on something) *can have*, by virtue of a well known quantum effect---the quantum Zeno effect---the physical effect of holding in place a pattern of neurobiological activity that tends to cause this imagined, or expected, or intended experience actually to occur. Such a pattern of brain activity---namely one such that its *persisting existence for a sufficiently long time* tends to cause the (experience of the) contemplated action to occur---is called a *template for action.* How it comes about that conscious free choices can, by virtue of the quantum psychophysical laws, cause a physically described *template for action* to be held in place for an extended period has been described elsewhere (in most detail in Stapp 2004), and will not be reviewed here.

The earlier articles, cited above, described many applications of twentieth-century physics to the data amassed in scientific studies pertaining to volition. The present article is an application to data pertaining to the character of conscious perception.

<u>Koch's The Quest for Consciousness and the NCC's</u>

Kock's title advertises his book as *The Quest for Consciousness*, and he speaks briefly, at the beginning (and also in several other places) about the mystery of consciousness---about the puzzle of *why certain activities in our brains are accompanied by conscious experiences.* But he says (p.xv) that "I argue for a research program whose supreme aim is to discover the neural correlates of consciousness, the NCC. These NCC's are defined (p.xv: p. 341) as:

"The minimal set of neuronal mechanisms or events jointly sufficient for a specific conscious precept or experience."

He immediately adds: "*This is what this book is about."*

Notice that he does not say "necessary and sufficient". This means that he is not suggesting an *equivalenc*e between a conscious experience and its neural correlate. Indeed, he says explicitly (p. 19) "The characters of brain states and of phenomenal states appear too different to be completely reducible to each other." Thus he distinguishes brain activities from streams of consciousness, and his definition allows a conscious experience to occur without the associated NCC occurring. He emphasizes, right from the start, that his book is about the NCC's, not about consciousness per se, and he acknowledges that it does not address the big mystery of consciousness: *why does it exist at all*. In fact, he notes (p.334) that his project of identifying the NCC's is what David Chalmers calls "The Easy Problem". Chalmers argues that solving this East Problem leaves unresolved The Hard Problem of consciousness: "why does it exist at all"; the mystery of why "the causation of behavior should be accompanied by subjective inner life."

Francis Crick, in his Foreward to Koch's book, says simply that "our strategy has been to try *firs*t to find the neural correlates of consciousness." [My emphasis.] But Koch says that "Characterizing the NCC is one of the ultimate scientific challenges of our times." This apparent elevation by Koch of the *first* part of the attack on the problem of consciousness, namely the "Easy" NCC part, from *preliminary* to *ultimate* status is probably connected to his assertion that: "I suspect that the Hard Problem …will disappear once one has solved the Easy Problem." (p. 334).

Can we identify the root of this major difference between Chalmers' position and Koch's? I think so! Chalmers, in his characterization of his position says. "I have not disputed that the physical world is causally closed or that behavior can be explained in physical terms." (Chalmers 1996, p. xiii). But this puts him essentially in the arena of classical physics, where consciousness is epiphenomenal: where conscious can do nothing in the physical world not done by the physical aspects alone. Given Chalmers's underlying acquiescence to epiphenomenalism, it is no wonder he encounters a hard problem.

Koch seemingly adopts a far more reasonable position! He apparently believes that consciousness can have real effects in the physical world. "I argue that consciousness gives access to … planning…Without consciousness you would be worse off." (p. 4) He asks " Why then, from the point of view of evolution, does consciousness exist? What survival value is attached to consciousness?" (p. 2) "In a fiercely competitive world consciousness must give the organism an edge over non-conscious zombies" (p. 231) "Operationally consciousness is needed for nonroutine tasks…(p. 12)." "The belief that phenomenal consciousness is real but impotent to influence events in the physical world continues to be remarkably widespread among modern philosophers. While this idea cannot, at this point, be proved false, it can be undermined… (p. 238).

Thus Koch appears to be saying, in many places, that, according to his thinking, consciousness has real physical effects. Presumably, his position is that consciousness *itself* is doing these things. No one doubts that neural activities, or brain activities, can have physical effects: the issue is only whether consciousness *itself, which he recognizes as being inequivalent to brain state,* can have such effects. If the NCC's, and the entailed brain states, by themselves, were able to do whole job, then there would be no justifiable reason to say that (inequivalent) *consciousness* has important effects, particularly in this context where the connection between consciousness and brain states is a key issue.

If Koch indeed believes that consciousness is *not* epiphenomenal---that it does things *not* done by the NCC's and the physically entailed brain states alone, and hence can have an evolutionary reason to exist---then he is going outside classical physics, which, because it enforces the principle of the causal closure of the physical, cannot allow anything not *equivalent* to some physically describable property to have physical consequences. Thus when Koch claims (p. 11) that his non-epiphenomenal "conscious is fully compatible with the laws of physics" he cannot be referring to the laws of classical physics, because classical physics makes consciousness, insofar as it is not equivalent to a physical property, epiphenomenal. Since he cannot, rationally, be referring to the laws of deterministic classical physics, he must be referring to the laws of quantum physics, which do allow our conscious choices to influence brain activity, without being equivalent to any physically describable brain activity!

Koch's explanations of the psycho-neurobiological data are in terms of the essentially classical idea of "victories of coalitions". Thus his model does not appear to bring in the quantum effects that can actually allow consciousness to possess the non-epiphenomenal status that he ascribes to it.

It must be noted, however, that Koch does not always maintain a sharp distinction between the effects of consciousness and the effects of its NCC's. For example, on page 18 he begins, promisingly, with the clean assertion "As I shall argue in Chapter 14, it is quite unlikely that consciousness is a mere epiphenomenon. Rather consciousness enhances the survival of its carrier." But he then immediately goes on to say "This means that the NCC activity must affect other neurons in some manner." But this is a non sequitur if, as his definition allows, the conscious event is not equivalent to its NCC, and can occur without it.

This basic conceptual problem (namely the epiphenomenal character of consciousness within classical physics) points to the logical need, if one respects the accepted laws of physics, to bring into the model the quantum effects that allow consciousness to be non-epiphenomenal. The interesting question, then, is whether this shift, demanded by rationality, has benefits beyond its mere rationality.

Differences between Koch's explanation of some neurobiological data and the physics-based explanation

Buds of Perception

One of the chief features of (conscious) perception is its discrete "all or nothing at all" character. William James [1911] said of percepts that: "your acquaintance with reality grows literally by buds or drops of perception. Intellectually and on reflection you can divide them into components, but as immediately given they come totally or not at all."

In view of the *continuous* character of the evolution of the state of a classically conceived brain it is puzzling, a priori, from a classical-physics standpoint, why perceptions should have this all-or-nothing-at-all character.

Koch's FIGURE 15.1B pertains to an experiment in which a subject observers a light source that is abruptly turned on, then maintained at a steady intensity for a certain interval, and then abruptly turned off. The figure shows a variable that Koch identifies as a "the 'critical' activity at the essential node for brightness". This variable rises with time until, at time $T_{ON,}$ it reaches a conjectured threshold, Threshold_{on}. This variable then becomes an NCC, and it remains so until, at time $T_{OFF,}$ it drops below an OFF threshold, Threshold_{off}. During the interval between T_{ON} and T_{OFF} this critical amplitude, labeled NCC, varies greatly, but the brightness of the light is experienced as *constant*. But why is the experienced brightness zero before $T_{ON,}$ then *constant* over the period between T_{ON} and $T_{OFF,}$ while the strength of the driving amplitude is greatly varying, and then abruptly zero again? One might expect, a priori, from classical physics, that if the *presence* of the experience depends on the strength of an amplitude then the *quality* of the experience should also depend upon the strength of that amplitude, and should therefore vary over a period during which the strength of driving amplitude is varying greatly. Why is this not the case?

Koch's explanation of the empirical constancy is this. Coalitions of neurons, firing in coordinated ways, battle for supremacy. When some coalition reaches "some sort of threshold" (p. 253) it brings about coordinated firings in many parts of the brain "until a stable equilibrium is reached." At this point an experience occurs. After a while, neural fatigue, and perhaps other factors, causes this state of stable equilibrium to break down, and the constant experience---say of brightness--- which has endured during the period of stable equilibrium, will abruptly cease to exist.

This process, as conceived of from a classical point of view, is purely mechanical (i.e., neuro-physiological) with consciousness the putative *consequence* of the mechanically maintained state of stable equilibrium, not the *cause* of a stable brain activity.

Once the macroscopic state of stable equilibrium that correlates with the experience comes mechanically into being it can become a controlling feature that can mechanically influence a lot of other brain activities, and one can say that the NCC exercises a sort of top-down control, which is correlated with the experience that this NCC is the correlate *of*. There could then be an "illusion" that the conscious experience *itself* is "causing" the activities that are actually being caused, purely mechanically, by the stable brain activity that is entailed by the varying NCC's.

This scenario poses the usual Hard Problem of why the perceptual experience exists at all, in view of the fact that the NCC is the sufficient physical cause of the physical action. Koch offers no solution, except his "suspicion", mentioned earlier, that the solution of the Easy Problem will produce the solution of the Hard Problem.

But, beyond that, an extrapolation of this model from this simple case to perceptions in general places a strong requirement on the neural dynamics: for every possible conscious percept there should be a potential state of stable equilibrium that maintains itself, relatively unchanging, in the presence of a range of stimuli that are sufficient to activate it.

One can of course *imagine* that a complex model of the brain exists that conforms to the principles of classical physics and that possesses all of the mechanical properties required by this classical scenario. But is it realistic to believe that such a model will someday be found, or would faithfully correspond to what is really going on, or would be useful. We know that a detailed *true* description of brain dynamics must involve the motions of ions flowing through ion channels. But then one is confronted by the fact that effects associated with Planck's constant must enter fundamentally into the dynamics, and that, in order to deal with the existence and the consequences of this universal constant of nature in a rationally coherent way, the founder's of quantum theory found themselves forced to abandon the basic precepts of classical physics, and build their theory instead upon the concept of psychophysical events. Classical mechanics emerges from that new theory only in an approximation that systematically exorcises the effects of our roles as *actors:* only in an approximation that eradicates the physical effects of the conscious choice that the founders of quantum theory found themselves forced to introduced, and that later physicists, in spite of intense efforts, have found no way to satisfactorily eliminate. In view of these developments in physics, what is the rational basis for an unwavering commitment to the claim that classical physics must be adequate.

And even if some adequate---though known to be physically false---classical model could be invented, would it be useful? A crucial recognition by the founders of quantum theory was that the essential output of a physical theory is a theoretical connection between what we can in practice choose to do and what the experienced consequences of such choices are likely to be, and that a key effect of Planck's constant is to prevent us from *ever* being able to follow, within *any* classical-type model, how such conscious inputs get transformed into experienced feedbacks. The founder's discovered that the causal gap in classical description entailed by the nonzero value of Planck's constant opened the way to a rational and useful replacement of the in-principle-inadequate classical model by a theory that explicitly brings into the dynamical structure the empirically accessible phenomenal facts concerning what we chooses to do and what we thereby learn. Why should neuroscientists not exploit such an empirically connected and potentially useful development in basic physics?

In the quantum ontology the perceptual moments are *intrinsically* discrete. The bud-like all-or-nothing character of perceptions need not be explained by imposing highly detailed, and perhaps impossible-to-meet, requirements on a classically conceived continuous neural dynamics. The discrete bud-like character of conscious events is dictated by mathematical requirements associated with the basic structure that the quantum physicists introduced in order to deal in a rationally coherent way with the limitations generated by the empirically founded need to replace numbers by operators. According to this quantum model, most of what goes on in the brain is controlled by the mechanical Process 2, which is the quantum mechanical counterpart of the single classical mechanical process. But this continuous process cannot rationally be the whole story, because it leads to physical states that are structurally different from what we perceive. To deal with this *logical* problem of the disparity between the smeared out nature of the quantum state, entailed by Planck's constant, and our relatively well defined states of knowledge about the objective world, supplied by our perceptions, orthodox quantum theory introduces discrete psychophysical events that bring the state of the physically described world into concordance with discrete increments of knowledge. Von Neumann's mathematical formulation of the quantum laws explicitly displays this discreteness, and exposes the mathematical difficulties that would ensue if one tried to replace the discrete events by a continuous process.

The physics-based model postulates, in general agreement with Koch's model, that a mind-brain event will occur when some physically described threshold is reached. But this abrupt all-or-nothing character of the event is now dictated by general mathematical requirements, not by imposing special dynamical demands upon a continuous physical process. Moreover, the empirical connections specified by the theory naturally accommodate the possibility that this psychophysical event will have a felt quality of "evaluation", perhaps a felt interest, that can trigger a rapid repeat of the discrete event. This would generate another repeat, etc., leading to a rapid sequence of essentially identical events. Such a sequence would hold in place a template for action, and would be experienced, just as we experience a movie of a static scene, as a prolonged constant experience. The constancy of the experience comes, however, from basic principles, not from some hypothesized dynamics that cannot actually be true for the same reason---the nonzero value of Planck's constant---that, according to physical principles, lies at the origin of the perceived discreteness.

The wagon wheel illusion

A closely connected phenomenon was discussed by Koch in the same Chapter 15. It is the "wagon wheel illusion". Every cowboy-movie goer is familiar with the fact that the wheels of a moving wagon sometimes seem to be turning backward. The explanation is simple: the flickering sequence of frames catches the wheels at times such that a later spoke has almost reached the position that an earlier spoke was at in the previous frame.

But there is a related empirical fact the needs explaining: The same illusion occurs in broad daylight!

At this point (p.264) Koch says "The implicit assumption up to this point has been that you and I experience the world in a continuous fashion: that the seamless nature of perceptual experience is reflected in the smooth waxing and waning of the NCC".

He goes on to say: "This is not the only possibility. Perception might well take place in discrete processing epochs, *perceptual moments, frames, or snapshots."*... "Within one such moment the perception of brightness, color, depth, and motion would be constant."

Koch goes on to say "Plenty of psychological data favors discrete perception, with the duration of each snapshot being quite variable, lasting anywhere between 20 and 200 msec." He cites an extreme example that was experienced by the neurologist Oliver Sacks. During a visual migraine Sacks did not see "movements as continuous but rather as a succession of "stills," a succession of different configurations and positions, but without any movement in-between, like the flickering of a film … run too slow."

Koch's explanation of the evidence in favor of discrete perception, in terms of what is going on in the continuously changing brain, harks back to his explanation of the constancy of the perception of the steady light. He says (p. 264): "Activity at the essential mode for some attribute would build up until a dominant coalition established itself and the NCC came into being. If the subject continued to attend to the stimulus, the dynamics of the system would have to be such that with some degree of regularity the NCC turn off and on again, constant within one perceptual moment but changing from one to the next before reaching a new quasi steady-state."

Again, Koch's explanation of this fundamentally bud-like character of perception depends upon very special vaguely imagined putative properties of the mind-brain, conceived of in classical mechanistic materialist terms that are known to be fundamentally false. On the other hand, the explanation of this discreteness within the framework of the empirically validated principles of quantum physics stems not from conjectured special properties of the classical approximation, which eliminates all the physical effects of our thoughts, but rather from mathematical demands arising from the need to incorporate rationally into our understanding of all natural phenomena, and most particularly ones depending significantly on atomic-level dynamics, the far-reaching effects of the universal constant of nature discovered at the end of the nineteenth century by Max Planck.

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A3. Support from Neuroscience.

Data important to the study of the mind-brain connection are collected by neuroscientists who monitor the activity of the brains of human subjects subjected to various kinds of stimuli or conditioning. Human subjects allow, by means of linguistic communication, access to the streams of consciousness that constitute the mind part of the mind-brain connection.

There is by now a large amount of data supporting the core idea of the quantum model, namely the existence, in association with consciousness, of characteristic oscillatory modes of neural activity that extend over macroscopic portions of the brain. For a summary see the article of E. Roy John (2003). In the quantum model developed here the oscillatory pattern of brain activity associated with a conscious effort is a template for action that will, if sustained, tend to bring into being the intended effect. The fact that such brain correlates of consciousness exist and have this macroscopic oscillatory structure is not in itself strong evidence in favor of the quantum model. However, failure to find such structures would have been strong evidence against this model. Hence one important test has been passed.

Perhaps partially under the influence of the classical idea that reality is built out of small localized parts that interact only with their neighbors, early neuroscientists had considered models of the mind-brain connection in which the cause of an individual conscious thought was far more localized---for example in the firing of individual neurons or small groups of neurons. Within that classical framework the proposition that an “atomic” thought should correspond to, or be, a spatially extended oscillatory motion is somewhat unnatural. But in quantum theory the extended character of the correspondence is an automatic consequence of the (necessarily) non local character of the Process 1 action. A Process 1 action that acts at a point would dump an infinite amount of energy into the brain and literally cause it to explode. Hence the Process 1 action must act over an extended region. The oscillatory character is a consequence of the fact that in quantum theory endurance resides in oscillatory activity, not in static being.

The paper of John also cites data that support the basic feature of the quantum model that the “stream of consciousness” consists of a sequence of discrete moments, or “perceptual frames,” each persisting for a fraction of a second. This feature is in line with the quantum model, in which a person’s stream of consciousness is the psychological aspect of a sequence of psychophysical events that are key dynamical components of the behaviour of his or her mind-brain.

John speaks also of a “comparator”. He says that “Only an unknown fraction of the neural activity at any moment may possess informational utility for the control of adaptive behaviour, which is how the brain contributes to survival. Some process beyond mere synchrony or nonrandomness must be invoked if the brain is to identify the relevant, informationally meaningful activity which is to be combined into an integrated percept. Further, what mechanism parses time into discontinuous intervals, ‘closes’ the microstate, and assesses the meaning of the different neuronal events which occur within the duration of the ‘perceptual frame’?”

John goes on to say: “The global population of coherent neurons must be evaluated, irrelevant activity (“noise”) excluded, and informationally significant activity (‘signal”) bound into a percept or ‘qualia’, a subjective instant of awareness. Otherwise, consciousness would be overwhelmed by a continuous sensory barrage.”

John’s “comparator” does essentially what the quantum Process 1 does: it picks out of a continuum of incipient possible templates for action the one template that actually occurs in association with a moment of experience.

John finds new neurophysiological evidence for the existence of his “comparator” process, or at least of the physical and experiential consequences of such a process. In trained animals, a meaningful input signal evokes a widespread “late” positive peak provided the conditioned response is elicited, but no such peak when performance fails. This late component is widespread and “was released from a nonsensory specific representational system”. “This system, established by previous learning, reflected contributions of memory, motivation, and affect related to stimuli.” In conscious human patients an electrical stimulation timed to disrupt the analogous late peak blocked perception. This late peak, which John associates with his “comparator”, seems to correspond to the actualization of the template for action specified by Process 1.

Within a classical framework one is obligated, in principle, to provide some micro-causal account of how all of these factors and features, memory, motivation, etc., can be represented by classically described brain activity, and how these features can then deterministically cause the activation of the widespread coordinated brain behaviour, and also the associated conscious experience. But, according to the precepts of quantum physics, a strictly deterministic account is impossible in principle, particularly in cases (such as those examined by John) of ambiguous input stimuli where a choice between one or the other of two trained responses is made.

It is clearly impossible in practice to know where every one of the calcium ions is going. So a classical solution is unachievable, both in practice and in principle. Quantum theory exploits this limitation in principle. Given the failure *in principle* of mechanistic determinism, quantum theory takes our conscious choices and experienced feedbacks to be in the theory what they are in actual empirical practice, namely the empirical inputs and resulting feedbacks. Quantum theory provides a rationally coherent practical alternative to the failed seventeenth century program for science. Considering the fact that physics constitutes the model or paradigm of scientific practice, it is bizarre that the essential intrusion of causally efficacious mind should be accepted in the basic science of mindless atoms, but be excluded from the basic science of conscious brains.

John considers the possibility of going over to a quantum mechanical approach but declares that “quantum mechanical proposals seem implausible and unlikely.” The reason he gives is that “There is no evidence that quantum mechanical processes can apply to slow processes which transpire in brains in times on the order of milliseconds and involve many cubic centimeters of cells at body temperature.” But the burden of proof is on the other side. Quantum physics must be used in principle unless there is reason why the uncertainty principle can be ignored. What is really implausible and unlikely is the idea that the dynamics of the mind-brain system can be adequately understood in terms of the micro-causal principles of classical physics that are known to be inadequate for key dynamical elements of brains (e.g., nerve terminals) and that leave out a key part of the mind-brain system, namely the mind. If one incorporates mind in the way specified by quantum theory then mind can have a large effect on brain process that involve many cubic centimeters of cells at body temperature, and that transpire in times on the order of milliseconds. It is the size of the effects of the uncertainty principle that sets limits on the effects of mind. In conscious human brains the effects of the uncertainty principle are in principle large because they are large in the dynamics of the nerve terminals, and uncertainties at the microscopic level tend to increase as they propagate up to the macroscopic level.

Of course, there are trillions of nerve terminals. If there is massive parallel processing then the uncertainties arising at the level of the individual stochastic process can be tremendously reduced. Indeed, much of our routine behaviour, although resting on a stochastic dynamics, is effectively deterministic. But in cases where habit and training do not suffice to dictate a well determined response, the microscopic underpinnings can resurface, and provide, in principle, room for a Process 1 intervention that is not deterministically fixed by the mathematically described state of the world.

A4. Dennett , Free Will, and the Quantum.

Many philosophers have tried to reconcile the mechanical determinism of classical physics with the concepts of free will and personal responsibility, and no one has tried harder than Daniel Dennett. In his recent book *Freedom Evolves* he views much of his 30-year effort, starting publicly with his 1984 book *Elbow Room*, through *Consciousness Explained* and *Darwin's Dangerous Idea*, as the building of the foundation for his attack on this problem. But, hard as he has tried, people have seemed incapable of properly understanding his main points, which are that "Our minds are just what our brains non-miraculously do,…"(p.xi), and that this premise is *compatible* with conscious "free will".

Dennett's main premise is a simple one, namely the "identity theory" thesis that each conscious thought is the very same thing as some brain activity, and, moreover, that brain activities can be regarded as being---insofar as they bear on these issues---governed by the mechanistic-deterministic laws of nineteenth century classical physics. But comprehension of his argument for the compatibility of this doctrine with the concept of free will seems to have eluded even his most sympathetic readers. He is frustrated (p. 20) with the defection of Steven Pinker, whom he had previously classified as one of the "responsible, cautious naturalists" like himself, but who, Dennett now says, continues to dally with what he describes as "mysterian doctrines of consciousness". Dennett is disappointed also with the fact that Robert Wright, who he says gives a fine presentation of most of the ideas that he will be presenting, finds himself unable to fully support Dennett's "uncompromising materialism". The "Mysterian doctrines of consciousness" are, apparently, the notion that our conscious thoughts and feelings---those elements of our streams of consciousness that are the only realities that we actually know---are non-identical to the theoretical inventions of Isaac Newton; and "uncompromising materialism" appears to mean equating any deviation from nineteenth century classical mechanical determinism to "defying the laws of physics" (p.1).

Dennett mentions also a book by Richard Dooling that includes an "insightful and accurate" précis of his (Dennett's) theory of conscious, but then "gets the part about free will dead wrong, *just the way that some real neuroscientists have done*." (Dennett's italics.) Thus Dennett, in spite of his intensive long-term effort to explain and defend his ideas, and despite his great expository skills, seems unable to get even these very serious like-minded people to understand or agree with him.

So what's going on here? Why are his ideas so hard to communicate to others?

Dennett (p. 224) quotes Tom Wolfe as noting that he, Dennett, (along with E. O. Wilson and Richard Dawkins) are "presenting elegant arguments" as to why mechanistic materialism does not diminish our self-image, but that the message "is not rippling out to the public. …The conclusion people out beyond the laboratory are drawing is: The fix is in! We are all hardwired! That, and: Don't blame me! I'm wired wrong!"

Dennett notes (p. 226) that he has already discussed this matter of free will and morality in Consciousness Explained, "but that discussion was obscure and difficult and needs refreshing." However, the extreme difficulty with Dennett's position---confirmed by the fact that he has written books and books explaining it, yet smart and sympathetic readers still don't get it---suggests that perhaps he is applying his great cleverness to establishing the truth of a false idea, namely the compatibility of (1), the idea that each of us is a mechanically governed automaton, with (2), the claim that each of us has a free will that adequately undergirds the concept of moral personal responsibility. Dennett says (p. 223) that "I've finally come to the conclusion that some people like the confusion." But the people who he thinks "like the confusion" include intelligent philosophers and scientists who are striving diligently to root out confusion. Why are twenty years of books insufficient to get his idea across to people such as these?

Dennett's view, and his problems, stem from a basic commitment to the mechanistic determinism of classical physics, coupled with the idea that consciousness is not an idle bystander. These commitments, combined, lead naturally to "identity theory": to the idea that consciousness is not a partner of matter, but an activity of matter. But his efforts to reconcile this mechanical view with rational moral philosophy tend to be self contradictory. Thus he extols Daniel Wegner's book *The Illusion of Conscious Will* by saying (p. 224): "I think Wegner's account of conscious will is the best I have ever seen", but then rejects Wegner's basic claim, and asserts the exact opposite, in a move he downplays as a mere tactical difference. He says that "Wegner thinks it is less misleading, more effective, to say that conscious will is an illusion" but that he, Dennett, thinks the better ‘tactic’ is “to make the same points by saying that no, free will is not an illusion.”

In order to construct a rational moral philosophy concordant with the precepts of classical physics Dennett wants to say that we are mechanistically deterministic beings that enjoy free will. This position requires a tortured twisting of the usual meanings of words that does not seems to pass muster: even supporters who want to agree with him seem unable to go along with these tamperings with normal meanings of words. The linguistic approach of deconstructing and reconstructing the meanings of the words does not seem to work for this problem.

This commentary on Dennett’s efforts to reconcile mechanistic determinism with rational moral philosophy is meant to emphasize that this problem is not one that can justifiably be claimed to have been solved by physicalist philosophers. Consequently, the warnings of scientists that the scientific foundation of contemporary philosophy of mind is not only wrong, *but essentially wrong,* cannot justifiably be brushed aside with authoritative assurances that philosophers now have things under good control, *despite their use of known-to-be-false science*. Tomes have been written, it is true, but volumes of argumentation, followed by incessant re-argumentation, and lack of consensus, is a sufficient cause to heed the claims of physicists that the cause of the persisting philosophical problem is the persisting use by physicalist philosophers of incorrect and inapplicable science.

Dennett asserts (p. 14) that his “fundamental perspective is naturalism, the idea that philosophical investigations are not superior to, or prior to, investigations of the natural sciences, but in partnership with those truth-seeking enterprises, and that the proper job for philosophers here is to clarify and unify the often warring perspectives into a single vision of the universe. That means welcoming the bounty of well-won scientific discoveries and theories…” Accordingly, he welcomes the offerings of (neo)Darwinism, yet generally ignores the seemingly crucial offerings of twentieth century physics.

In his chapter 4 Dennett does consider the idea that the indeterminism of quantum theory might open the door to the entry of a free will that can aid in the construction of a rational moral philosophy. He poses the right question: “How can the indeterminism of quantum physics be harnessed to give us a clear, coherent picture of a human agent exercising this wonderful free will?” However, he then re-poses the question in a very different way: “How, exactly, could subatomic indeterminism yield free will?” Then, rather than considering quantum theory itself, he proceeds at great length to discredit a model constructed by Robert Kane, who introduces a random element of indeterminism to break the absolute determinism of classical physics in the hope of thereby exploiting quantum theory to open the way to a satisfactory concept of free will. But the replacement of intentional conscious choices by random or whimsical elements certainly cannot provide a rational basis for morality. *On the other hand, the free choices of human beings that enter so importantly into orthodox quantum theory are not the elements of randomness of* *that theory*. *It is not these human choices that are random in quantum theory. The randomness enters into nature's responses to the probing actions that we freely choose.* So Dennett, like Searle, completely misses the reason why quantum theory should be so relevant: namely *the freedom it grants to human agents* to act on the basis of reasons and evaluations that are controlled neither by whimsy nor mechanism..

Later on (p. 223) Dennett asserts that he believes there is a morally important non-supernatural free will, but that it is "just not what you probably thought it was." But what does the scientifically inclined and literate reader think a non-supernatural free will is?

Nature certainly contains non-supernatural thoughts and feelings: our own thoughts and feelings are such realities. Both Dennett and quantum physics agree that they are causally efficacious, and are in some sense "free". But it is Dennett's own conceptual bias, not contemporary science, that insists that each of these components of a stream of conscious experiences is *identical* to some mechanistic material processes. It is his rigid commitment to the failed ideology of classical physics that is the underlying source of the difficulties he encounters: it is the nineteenth-century-blinders that foists upon him the impossible task of showing that mechanically deterministic automata possess conscious free wills that can underpin a rational moral philosophy.

The bounty offered by quantum theory is not the gift of meaningless whimsy. It is the introduction of immaterial causes. The indeterminism introduce by quantum theory comes in two forms. One consists of the random "choices on the part of nature". These choices conform to certain statistical laws that are closely tied to the mathematical structure that replaces the material structure postulated by classical physics. The other form of indeterminism stems from conscious volitions that are physically efficacious, yet "free" in the sense that they are not fixed by any yet-known laws. These choices are part of the natural order: they are not supernatural. And they occupy a well defined and essential place orthodox contemporary physical theory.

Dennett correctly posed the key question: "How can the indeterminism of quantum physics be harnessed to give us a clear, coherent picture of a human agent exercising this wonderful free will?" The main content of the present book has been to explain in non-technical terms how this is done by orthodox contemporary physics.

A5. Knowledge, Information, and Entropy

The book *John von Neumann and the Foundations of Quantum Physics* contains a fascinating and informative article written by Eckehart Kohler entitled "Why von

Neumann Rejected Carnap's Dualism of Information Concept." The topic is precisely the core issue before us: How is knowledge connected to physics? Kohler illuminates von Neumann's views on this subject by contrasting them to those of Carnap.

Rudolph Carnap was a distinguished philosopher, and member of the Vienna Circle. He was in some sense a dualist. He had studied one of the central problems of philosophy, namely the distinction between *analytic* statements and *synthetic* statements. (The former are true or false by virtue of a specified set of rules held in our minds, whereas the latter are true or false by virtue their concordance with physical or empirical facts.) His conclusions had led him to the idea that there are two different domains of truth, one pertaining to logic and mathematics and the other to physics and the natural sciences. This led to the claim that there are "Two Concepts of Probability," one logical the other physical. That conclusion was in line with the fact that philosophers were then divided between two main schools as to whether probability should be understood in terms of abstract idealizations or physical sequences of outcomes of measurements. Carnap's bifurcations implied a similar division between two different concepts of information, and of entropy.

In 1952 Carnap was working at the Institute for Advanced Study in Princeton and about to publish a work on his dualistic theory of information, according to which epistemological concepts like information should be treated separately from physics. Von Neumann, in private discussion, raised objections, and Pauli later wrote a forceful letter, asserting that "I am quite strongly opposed to the position you take." Later he adds "I am indeed concerned that the confusion in the area of the foundations of statistical mechanics not grow further (and I fear very much that a publication of your work in its present form would have this effect)."

Carnap's view was in line with the Cartesian separation between a domain of real objective physical facts and a domain of ideas and concepts. But von Neumann's view, and also Pauli's, linked the probability that occurred in physics, in connection with entropy, to *knowledge*, in direct opposition to Carnap's view that epistemology (considerations pertaining to knowledge) should be separated from physics. The opposition of von Neumann and Pauli significantly influenced the publication of Carnap's book.

This issue of the relationship of knowledge to physics is the central question before us, and is in fact the core problem of all philosophy and science. In the earlier chapters I relied upon the basic insight of the founders of quantum theory, and upon the character of quantum theory as it is used in actual practice, to justify the key postulate that Process 1 is associated with knowing, or feeling. But there is also an entirely different line of justification of that connection developed in von Neumann's book, *Mathematical Foundations of Quantum Mechanics*. This consideration, which strongly influenced his thinking for the remainder of his life, pertains to the second law of thermodynamics, which is the assertion that entropy (disorder, defined in a precise way) never decreases.

There are huge differences in the quantum and classical workings of the second law. Von Neumann's book discusses in detail the quantum case, and some of those differences. In one sense there is no nontrivial objective second law in classical physics: a classical state is supposed to be objectively well defined, and hence it always has probability one. Consequently, the entropy is zero at the outset and remains so forevermore. Normally, however, one adopts some rule of "coarse graining" that destroys information and hence allows probabilities to be different from unity, and then embarks upon an endeavor to deduce the laws of thermodynamics from statistical considerations. Of course, it can be objected that the subjective act of choosing some particular coarse graining renders the treatment not completely objective, but that limited subjective input seems insufficient to warrant the claim that physical probability is closely tied to knowledge.

The question of the connection of entropy to the *knowledge and actions of an intelligent being* was, however, raised in a more incisive form by Maxwell, who imagined a tiny "demon" to be stationed at a small doorway between two large rooms filled with gas. If this agent could distinguish different species of gas molecules, or their energies and locations, and slide a frictionless door open or closed according to which type of molecule was about to pass, he could easily cause a decrease in entropy that could be used to do work, and hence to power a perpetual motion machine, in violation of the second law.

This paradox was examined Leo Szilard, who replaced Maxwell's intelligent "demon" by a simple idealized (classical) physical mechanism that consumed no energy beyond the apparent minimum needed to 'recognize and responded differently to' a two-valued property of the gas molecule. He found that this rudimentary process of merely 'coming to know and respond to' the two-valued property transferred entropy from heat baths to the gaseous system in just the amount needed to preserve the second law. Evidently nature is arranged so that what we conceive to be the purely intellectual process of coming to know something, and acting on the basis of that knowledge, is closely linked to the probabilities that enter into the constraints upon physical processes associated with entropy.

Von Neumann describes a version of this idealized experiment. Suppose a single molecule is contained in a volume V. Suppose an agent comes to know whether the molecule lies to the left or to the right of the center line. He is then in the state of being able to order the placement of a partition/piston at that line and to switch a lever either to the right or to the left, which restricts the direction in which the piston can move. This causes the molecule to drive the piston slowly to the right or to the left, and transfer some of its thermal energy to it. If the system is in a heat bath then this process extracts from the heat bath an amount 'log 2' of entropy (in natural units). Thus the *knowledge* of which half of the volume the molecule was in is converted into a decrement of "log 2' units of entropy. In von Neumann's words, "we have exchanged our knowledge for the entropy decrease k log 2." (k is the natural unit of entropy.)

What this means is this: When we conceive of an increase in the "knowledge possessed by some agent" we must not imagine that this knowledge exists in some ethereal kingdom, apart from its physical representation in the body of the agent. Von Neumann's analysis shows that the change in knowledge represented by Process 1 is quantitatively tied to the probabilities associated with entropy.

Among the many things shown by von Neumann are these two:

(1) The entropy of a system is unaltered when the state of that system is evolving solely under the governance of Process 2.
(2) The entropy of a system is never decreased by any Process 1 event.

The first result is analogous to the classical result that if an objective "probability" were to be assigned to each of a countable set of possible classical states, and the system were allowed to evolve in accordance with the classical laws of motion then the entropy of that system would remain fixed.

The second result is a nontrivial quantum second law of thermodynamics. Instead of coarse graining one has Process 1, which in the simple 'Yes-No' case converts the prior system into one where the question associated with the projection operator P has a definite answer, but only the *probability* associated with each possible answer is specified, not an answer itself.

One sees, therefore, why von Neumann rejected Carnap's attempt to divorce knowledge from physics: large tracts in his book were devoted to establishing their marriage. That work demonstrates the quantitative link between the increment of knowledge or information associated with a Process 1 event and the probabilities connected to entropy. This focus on Process 1 allowed him to formulate and prove a quantum version of the second law. In the quantum universe the rate of increase of entropy would be determined not by some imaginary and arbitrary coarse graining rule, but by the number and nature of objectively real Process 1 events.

Kohler discusses another outstanding problem: the nature of mathematics. At one time mathematics was imagined to be an abstract resident of some immaterial Platonic realm, independent in principle from the brains and activities of those who do it. But many mathematicians and philosophers now believe that the process of doing mathematics rests in the end on mathematical intuitions, which are essentially aesthetic evaluations.

Kohler argues that von Neumann held this view. But what is the origin or source of such aesthetic judgments?

Roger Penrose based his theory of consciousness on the idea that mathematical insight comes from a Platonic realm. But according to the present account each such illumination, like any other experience, is represented in the quantum description of nature as a picking out of an organized state in which diverse brain processes act together in an harmonious state of mutual support that leads on to feedbacks that sustain the structure by recreating it with slight variations A mathematical illumination is a grasping of an *aesthetic* quality of order in the quantum state of the agent's brain/body. Every experience of any kind is fundamentally like this: it is a Process 1 grasping of a state of order that tends recreates itself in a slightly varied form.

This notion that each Process 1 event is a felt grasping of a state in which various sub-processes act in concert to produce an ongoing continuation of itself provides a foundation for answering in a uniform way many outstanding philosophical and scientific problems. For example, it provides a foundation for a solution to a basic issue of neuroscience, the so-called "binding problem". It is known that diverse features of a visual scene, such as color, location, size, shape, etc. are processed by separate modules located in different regions of the brain. This understanding of the Process 1 event makes the felt experience a grasping of a non-discordant quasi-stable mutually supportive combination of these diverse elements as a unified whole. To achieve maximal organizational impact this event should provide the conditions for a rapid sequence of re-enactments of itself. Then this conception of the operation of von Neumann's Process 1 provides also an understanding of the capacity of an agent's thoughts to control its bodily behavior. The same conception of Process 1 provides also a basis for understanding both artistic and mathematical creativity, and the evolution of consciousness in step with the biological evolution of our species. These issues all come down to the problem of the connection of knowings to physics, which von Neumann's treatment of entropy ties to Process 1.

Kohler quotes an interesting statement of von Neumann, but then draws from it conclusions about von Neumann's views that go far beyond what von Neumann actually said.

Von Neumann points out that in classical mechanics one can solve the problem of motion either by solving differential equations (the local causal mechanistic approach) or by using a global least action (or some other similar) approach. This latter method can be viewed as "teleological" in the sense that if initial and final conditions are specified then the principle of least action specifies the path between them. He goes on to say that he is:

"not trying to be facetious about the importance of keeping teleological principles in mind when dealing with biology; but I think one hasn't started to understand the problem of their role in biology until one realizes that in mechanics, if you are just a little bit clever mathematically, your problem disappears and becomes meaningless. And it is perfectly possible that if one understood another area then the same thing might happen."

The pertinent "other area" is psychology, or the problem of mind.

The first point is that von Neumann's statement is very cautious: he says that it is "perfectly *possible* that *if* one understood another area the same thing *might* happen." There are three weak links: "possible", "if", and "might."

Kohler's conclusion is far less cautious. He follows the above quotation with the assertion:

"Here von Neumann warns biologists against overstressing goal-directed activity since this can always be reformulated *causally*."

Von Neumann said no such thing. He merely points out that in classical mechanics certain global least action principles are equivalent to local causal mechanistic rules. That falls far short of claiming that *all* goal-directed activity can be expressed in least-action terms, or that in *non-classical* cases such a least-action formulation would necessarily be equivalent to a local causal mechanism. Von Neumann recognizes this as a possibility, not a necessity.

In quantum physics the Process 2 part of the dynamics is derived from the quantization of the classical law. Hence it might be contended that *for this Process 2 part of the dynamics* an equivalence holds between "teleological" and "causal" formulations. But the connection to mind involves Process 1. It is far from obvious that the equivalence found in classical mechanics will carry over to Process 1. In the first place, Process 1 involves non-local operators P, and that alone would appear to block reduction to local causation. In the second place, Process 1 drops out of the dynamics when one goes to the classical limit, which is the limit in which all effects involving Planck's constant are neglected. Hence Process 1 is, in this sense, non-classical or anti-classical. Hence there is no reason to believe that equivalences occurring in classical physics will carry over to Process 1. Such a connection "might possibly" hold, but it is surely not required to hold by anything we know today.

Kohler goes on to state that:

"Based on his general approach, one may say von Neumann was a psycho-physical reductionist who thought human intelligence could in principle be presented and explained on a physical level --- in particular, neurologically, in terms of nerve nets. Between the physiology of nerves and the physics of computer devices von Neumann recognized no difference in functional capacity."

That last statement seems tremendously at odds with the conclusions of von Neumann's final work, "The Computer and the Brain," which emphasized the huge differences between brains and computers. But, that point aside, the fact that von Neumann did much work on classically describable computers does not imply that he was committed to the view that *human intelligence* could be understood in classical terms. Von Neumann may indeed have not excluded that possibility, but I doubt that any statement of his shows him to be committed to the position that human intelligence, and, more importantly, his Process 1, can be explained in local mechanistic terms. The statement quoted above certainly fails to justify such a conclusion.

A6. The Basis Problem in Many-Worlds Theories.

In a Many-Worlds (or Many-Minds) approach the quantum state under consideration is the state of the whole universe. It is represented by a generalization of an N-by-N matrix. The rows and columns of this "matrix" are labeled not by a set of integers (i.e., whole numbers), but rather by an index, here called I, that specifies the location of every particle in the universe. (Actually, one must consider also "fields", but I shall ignore that complication in this account.) A subsystem is represented by averaging over all variables except those corresponding to that subsystem

The physical system S is represented by a "matrix" S(I,I'), where I specifies a possible location for every "particle" in the classical conception of the system, and I' represents another possible location of every such particle.. The "diagonal" elements are those for which I = I'. The far off-diagonal elements are suppressed by the interaction with the environment, but the slightly off-diagonal elements remain generally nonzero, and they lock the whole near-diagonal structure together. The region where S(I,I) is significantly different from zero remains large, even after the effects of interaction with the environment are taken into account. In a world governed exclusively by Process 2, starting from the time of the big bang, there will be a huge smearing effect. Consequently, this nearly diagonal portion of S(I,I') cannot be expected to be broken up into a collection of different, isolated, distinct regions that could be associated with different experiences. Therefore, the separation of the state of the universe into distinct parts corresponding to different experiences seems clearly to require something besides Process 2 alone. Anyone who claims that the Schroedinger evolution (Process 2) alone is sufficient to separate this very smeared out state into a *countable* set of components corresponding to different experiences needs to explain how this comes about.

The way this problem is resolved in orthodox quantum theory is to introduce a mathematical transformation that allows each of the possible cloud-like quantum states to be represented as a single "vector" in an appropriate space.

The real situation involves a space of an infinite number of dimensions, but the idea of a *vector in a space* can be illustrated by the simple example in which the space has just two dimensions. Take a flat sheet of paper and put a point on it. (Imagine that your pencil is infinitely sharp, and can draw a true point, and perfectly straight lines of zero width.). Draw a straight line that starts at this point, called "the origin", and that extends out by a certain amount in a certain direction. That directed line segment, or the displacement from the origin that it defines, is a *vector* in a two-dimensional space.

Any pair of unit-length vectors in this space that are perpendicular to each other constitute a “basis” in this two-dimensional space. (They are in fact an “orthonormal basis”, but that is the only kind of basis that will be considered here.) Because any basis (pair) rigidly rotated by any angle gives another basis (pair), there is an infinity of possible ways to choose a basis in a two-dimensional space.

Given a basis, there is a unique way of decomposing any vector into a sum of displacements, one along each of the perpendicular basis vectors. The individual terms are a set of perpendicular vectors called the *components* of the vector in this basis.

An n-dimensional (vector) space is similar, but has n dimensions instead of just two. This means that it allows not just two mutually perpendicular basis vectors, but n of them. As a mathematically well defined idea this is possible. There are clearly an infinite number of ways to choose a basis in any space of two or more dimensions. For any n, and any basis in the n-dimentional space there is a unique way of decomposing any vector in that space into a sum of displacements along each of the mutually perpendicular basis vectors.

A quantum state of a system can be represented by a vector in a space of an infinite number of dimensions. Much of von Neumann’s book was devoted to the fine points of how this could be done in a mathematically well defined way. Although the number of basis vectors is infinite, it is countably infinite: the basis vectors can be placed in one-to-one correspondence to the numbers 1, 2, 3, … That means that, *given a basis,* one has a unique decomposition of the state of the system into a *countable* set of components..

But why is this choice of a basis so essential? Let me explain.

If you have just a countable set of states then you could, for example, assign probability ½ to the first state, probability ¼ to the second state, probability ⅛ to the third, and so on, and the total probability will add to one (unity), as a sum of probabilities should. But if the probability S(I,I) is a continuous function of I, as it would be if only process 2 were present, and there were a distinct experience for each value of I, and S(I,I) were non-zero for some value of I , then S(I,I) would necessarily be larger than some (perhaps very tiny) non-zero number, say e, in some finite region. (This follows from the continuousness of S(I,I).) But there are an infinite number of possible values of I in any finite interval, and if each one represents a real existing different experience, then the total probability for an experience to occur would be at least infinity times e, or infinity.

The main interpretive idea of quantum theory is to use a generalization of the theorem of Pythagoras to resolve this problem. That theorem says that the sum of the squares of the two shorter sides of a right triangle is equal to the square of the longer side. This rule generalizes to a figure in a space of a countable number of dimensions in the following way: If any vector of unit length is decomposed into a sum of components each perpendicular to every other one, then the sum of the squares of the lengths of these components is one (unity). Using this law we can guarantee that if, for some preferred basis, each basis vector corresponds to some experience, and for any state represented by a unit vector just prior to the collapse, the probability for a given experience to occur is given by the square of the length of the component directed along the associated basis vector, then the probabilities for the alternative possibilities will sum to unity (i.e., to one), as they should.

But this preferred basis is just one of a continuum of mathematically allowed possibilities. So the main problem in principle in the construction of a satisfactory quantum theory is: How is a particular set of mutually perpendicular directions in the infinite dimensional space singled out from the infinity of other possible sets. What fixes the preferred basis?

Process 2 specifies the way that the vector that represents the state of the system continuously evolves, but it does not, in any known way, select also a basis. If Process 2 is the only process in nature then one is faced with the problem of showing how this evolving state separates, by itself, in some definite way into a countable set of components each corresponding both to a distinct experience and to a different subset of *some* set of perpendicular directions (in the Hilbert space). This problem is the problem lurking behind the Zurek's very true words that "Much remains to be done."

Orthodox quantum theory solves this basis problem by invoking another process, Process 1, which is fundamentally different from the local mechanical Prosess 2. It is intrinsically nonlocal, and connects the purely mechanical features of scientific theory and practice to the empirical data enfolded in our streams of conscious experiences.

A7. Gazzaniga's "The Ethical Brain".

Michael S. Gazzaniga is a renowned cognitive neuroscientist. He was Editor-in-Chief of the 1447 page book *The Cognitive Neurosciences,* which, for the past decade, has been the fattest book in my library, apart from the 'unabridged'. His recent book *The Ethical Brain* has a Part III entitled "Free Will, Personal Responsibility, and the Law". This Part addresses, from the perspective of cognitive neuroscience, some of the moral issues that have been dealt with in the present book. The aim of this Part III is to reconcile the materialist idea that brain activity is *determined* with the notion of *moral responsibility*, which normally depends upon the idea that we human agents possess *free will*.

Gazzaniga asserts: “Based on the modern understanding of neuroscience and on the assumptions of legal concepts, I believe the following axioms: Brains are automatic, rule-governed, determined devices, while people are personally responsible agents, free to make their own decisions.”

One possible interpretation of these words---the quantum-theoretic interpretation---would be that a person has both a mind (his stream of conscious thoughts, ideas, and feelings) and a brain (made of neurons, glia, etc), and that his decisions (his conscious moral choices) are free (not determined by any known law), and that, moreover, the rules that govern his brain *determine* the activity of his brain *jointly* from the physically described properties of the brain *combined* with these conscious decisions. That interpretation is essentially what orthodox (von Neumann) quantum mechanics---and also common sense intuition---asserts.

If this interpretation is what Gazzaniga means, then there is no problem. But I believe that this is not what Gazzaniga means. Earlier on he said: “

> The brain determines the mind, and the brain is a physical entity subject to all the rules of the physical world. The physical world is determined, so our brains must also be determined.

This seems to be suggesting that by “determined” he means determined solely by physically described properties, as would be the case if the concepts of classical physics were applicable. However, what he actually said was that “the brain is a physical entity subject to all the rules of the physical world.” The rules of the physical world, as specified by contemporary (orthodox quantum) theory, explain how the brain is governed in part by the brain and in part by our conscious choices, which themselves are not governed by any known laws. If this physics-based understanding of “determined” is what Gazzaniga means then there is no difficulty in reconciling the fact that an agent’s brain is “determined” with the fact that this agent’s person is “free”: the agent’s *brain* is determined partly by his brain and partly by his conscious free choices, and hence the *person* whose actions this brain controls is likewise jointly controlled by these two factors, neither of which alone suffices.

If this contemporary-physics-based interpretation is what Gazzaniga meant, then he could have stopped his book right there: that interpretation is in complete accord with common sense, and with normal ethical theory. Thus the fact that he did not stop, but went on to write his book, including Part III, suggests that he is using not the quantum mechanical meaning of “determined”; but rather the meaning that would hold in the classical approximation, which exorcizes all the physical effects of our conscious choices. Indeed, he goes on to say:

> If our brains are determined ,,, then … Is the free will we seem to experience just an illusion? And if free will is an illusion, must we revise our concepts of what it means to be personally responsible for our actions?

I am assuming in this appendix that Gazzaniga is adhering essentially to nineteenth century physics, so that "determined" means automatically/mechanically determined by physically described properties alone, like a clock, and that he is thus endeavouring to address the question: How can one consider a person with an essentially clocklike body-brain to be morally responsible for his actions? How can we uphold the concept of ethical behaviour within the confines of an understanding of nature that reduces each human being to a mechanical automaton?

Gazzaniga's answer is built upon a proposed restructuring (redefining) the meanings of both "free will" and "moral responsibility". Following an idea of David Hume, and more recently of A. J. Ayer, the word "free" is effectively defined to mean "unconstrained by external bonds". Thus a clock is "free" if the movements of its hands and cogs are not restricted by external bonds or forces. However, the "Free Will" of traditional ethical theory refers to a type of freedom that a mechanically controlled clock would <u>not</u> enjoy, even if it had no *external* bonds. This latter---morally pertinent---kind of free will is specifically associated with consciousness. Thus a physically determined clock *that has no consciousness* <u>is not subject</u> to moral evaluation, even if it is not constrained by external bonds, whereas a person possessing a conscious "will" that is physically efficacious, yet not physically determined, <u>is subject</u> to moral evaluation when he is not constrained by external bonds. Thus the morally pertinent idea of "possessing free will" is not the same as "unconstrained by external bonds or forces." The Hume/Ayer move obscures the morally pertinent idea of freedom, which is intimately linked to consciousness, by confounding it with different idea that does not specifically involve consciousness. This move throws rational analysis off track by suppressing (on the basis of an inapplicable approximation) the involvement of consciousness in the morally relevant conception of "free will".

Ethical and moral values traditionally reside in the ability of a person to make discerning conscious judgments pertaining to moral issues, coupled with the capacity of the person's conscious effort to willfully force his body to act in accordance with the standards he has consciously judged to be higher, in the face of strong natural tendencies to do otherwise. The whole moral battle is fought in the realm of conscious thoughts, ideas, and feelings. Where there is no consciousness there is no moral dimension. *Moreover*, if consciousness exists but is permitted by general rules to make no physical difference---that is, if consciousness is constrained by the general laws to be an impotent witness to mechanically determined process---then the seeming struggle of will becomes a meaningless charade, and the moral dimension again disappears.

It is the imposition, by virtue of the classical approximation, of this law-based kind of impotency that eliminates the moral dimension within that approximation. The morally pertinent free will is eradicated by the classical approximation even if there are no external bounds. Calling a system “free” just because it is *not constrained by external bonds* does not suffice to give that system the kind of free will that undergirds normal ethical ideas.

Gazzaniga’s attack on the problem has also a second prong. He avers that “Personal responsibility is a public concept.” He says of things such as personal responsibility that:
“Those aspects of our personhood are---oddly---not in our brains. They exist *only* in the relationships that exist when our automatic brains interact with other automatic brains. They are in the ether.”

This idea that these pertinent things “are in the ether” and “exist only in the relationships” is indeed an *odd* thing for a materialistically-oriented neuroscientist to say. It seems mystical. Although ideas about personal responsibility may indeed arise only in social contexts, one would normally say that the resulting *ideas* about personal responsibility *exist in the streams of consciousness of the interacting persons,* and a materialist would be expected to say that these ideas are “in” or are “some part of” the brains of those socially interacting persons. Yet if the causes of self-controlled behaviour are wholly in the brains and bodies of the agents, and these brains and bodies are automatically determined by the physically described body-brain alone, then it is hard to see how these agents, as persons, can have the kind of free will upon which our moral and ethical theories are based. Some sort of odd or weird move is needed to endow a person with morally relevant free will if his body and brain are mechanically determined.

But if some sort of weirdness is needed to rescue the social concept of personal responsibility, then why not use “quantum weirdness”. The quantum concepts may seem weird to the uninitiated, but they are based on science, and they resolves the problem of moral responsibility by endowing our conscious choices with causal influence in the selection of our physical actions.

It is hard to see the advantage of introducing the changes described by Gazzaniga compared to the option of simply going beyond the in-principle-inadequate classical approximation. Why do thinkers dedicated to rationality resist so tenaciously the option of accepting (contemporary orthodox quantum) physics, which says that our conscious choices intervene, in a very special and restricted kind of way, in the mechanically determined time development of the physically described aspects of a system---during the process by means of which the conscious agent acquires new knowledge about that system? Because acquiring new knowledge about a system normally involves a probing of the system, it is not at all weird that the system being examined should be affected by the extraction of knowledge from it, and hence come to depend upon how it was probed.
The advantages of accepting quantum mechanics in cognitive neuroscience, and ultimately in our lives, are:

1. It is compatible with basic physical theory, and thus will continue to work in increasingly complex and miniaturized empirical situations.

2. It ties, in a prescribed manner, physically described data to the psychologically described data contained in the reports of human subjects.

3. It removes the incoherency of an ontological element that contains the empirical data, yet resides in a realm that has no law-based connection to the flow of physical events.

4. It allows the co-evolution of mind and brain to be understood, because each of these two parts contributes to the dynamics in a way that is linked to the other by specified laws.

5. It provides for a free will of the kind needed to undergird ethical theory.

6. It produces a science-based image of oneself, not as a freak-accident out-cropping, riding unnoticed like a piece of froth on an ocean, but rather as an active integral component of an incredibly intricate and deeply interconnected world process that is responsive *by known laws* to every person's mind-based inputs of meaning and value.

A8. A Whiteheadian-Type Model

In the foregoing parts of the book I have maintained an extremely conservative stance. I have strictly adhered to orthodox contemporary physical theory, in its von Neumann form---extended to relativistic quantum field theory by Tomonaga and Schwinger---and have merely enhanced the causal efficacy of mental effort by making use of the quantum Zeno effect. Nothing more is needed, insofar as one seeks only a theoretical foundation compatible with contemporary physics for the study of the connection between human minds and human brains. However, several readers of earlier versions complained that they were dissatisfied, because they felt that if a leap from pragmatism to ontology is made then a more complete ontology is needed, namely one that provides an idea of what was going on before life appeared.

A number of physicists, including Abner Shimony (1965, 1993), Rudolf Haag (1996), and myself (Stapp, 1977, 1979) have emphasized the seeming appropriateness of the ontological ideas of Alfred North Whitehead. Those ideas, even though they have been tied into quantum physics in the references cited above, fall under the heading of "speculative philosophy". Whitehead was stimulated by early developments in quantum theory but relied more on philosophical and logical considerations than on empirical data, or the detailed structure of relativistic quantum field theory. But in view of the way basic physical theory has been moving in recent years it is not clear that the “speculations” of Whitehead are completely different in kind from what now frequently appears in physics journals.

I do not wish to change the main thrust of this book by delving into cosmological issues in any great detail. On the other hand, my own thinking does place the “scientific” considerations expounded earlier in a provisional Whiteheadian context.

I do not commit myself to this Whiteheadian overview. But, for what it is worth, I shall, in this final appendix, sketch out my own favored interpretation and extension of the Whiteheadian ontology. I make no claim that what I say is exactly in accord with Whitehead, though I have been aided in that connection by many communications with the Whiteheadian scholar Jorge Nobo.

Whitehead’s ontology is, like the von Neumann ontology, built of a growing collection of psycho-physical events. Whitehead calls them “actual occasions”. Each such occasion is a process that has stages, from an initial stage to a final stage. In the initial stage the occasion receives data from the occasions that are already complete. Upon its completion an occasion creates potentialities that are *active,* in the sense that they tend to thrust themselves, whole or in part, into occasions that are yet to be born.

There is a single common *process time*, and each occasion occupies a certain definite interval in this process time. These intervals can overlap, and occasions with overlapping intervals are called “contemporaries”, or “contemporaneous”. If the entire interval associated with occasion A lies earlier than the entire interval associated with occasion B then A is said to lie in the causal past of B.

Each occasion occurs in *process* time. Its initial data, received from its causal past, fixes an associated region in space-time. At any moment in process time the collection of space-time regions associated with those occasions that are already complete fill up the part of space-time that lies earlier than some space-like surface. [See the discussion in Chapter 10 of the Tomonaga-Schwinger formulation of relativistic quantum field theory.] Thus as the collection of actual occasions grows, the space-like surface “now” advances in an ordered sequence of forward jumps. A quantum state of the universe is defined on each of these surfaces.

Each actual occasion has both a mental “pole”, or aspect, and a physical “pole”, or aspect. Thus each occasion is a psycho-physical event that is associated with a particular space-time region.

Associated with each such event is a Process 2 action that propagates the state of the universe just prior to the event to a provisional state just after the event. According to the principles of relativistic quantum field theory, only those aspects of the quantum state that are located on the boundary of the associated space-time region are altered by this Process 2 action. There is also a Process 1 action that reduces this provisional state just after the Process 2 action into a *sum* two parts, that can be labeled ‘Yes’ and ‘No’. [Predictions pertaining to faraway regions are not changed by this Process 1 action.] Then there is a Process 3 reduction to either the ‘Yes’ state or the ‘No’ state. [Predictions pertaining to faraway regions can be changed by this Process 3 action.]. The predictions of quantum theory then emerge from the assumption that if the part of state of the universe associated with some region is sufficiently isolated, physically, from all possible observing systems then the ‘No’ state is empty: Process 1 does nothing. Process 2 does it all.

The Process 1 separation of the final state into two parts is made by the actual occasion itself. This occasion takes its initial data, thrust upon it by its causal past, and produces a separation into two parts of the provisional state generated by Process 2. The initial data consists of the (quantum) state of the universe just before the occasion, together with the final mental contents of all of the already completed occasions. Thus the mental contents of all of the already completed occasions are part of the “grist” from which the new occasion constructs itself.

A human being is a “society” of actual occasions that hang together over an extended period of time, with continuity in both space and time, and, under normal conditions, with a certain kind of strong linkages among the their mental aspects.

In the minimalist ontology described in the text the physical aspects are assumed to control Process 1, except that a certain feel of an event is allowed to entail a repetition of essentially the same event a short time later. On the other hand, the Whitehead structure, although not structureless, is very general, and thus could be made to accommodate data that could not be accommodated by that minimalist option. This flexibility is both a boon, because it may allow data to be accommodated that is not understandable within the minimalist structure, and also a bane, because it does not allow one to so easily identify questionable data involving consciousness as being strictly incompatible with any rationally coherent ontology that encompasses the basic predictions of quantum theory.

It is important that this Whitehead ontology accommodates the “marching band” structure of our streams of consciousness described by William James and discussed in my earlier book (Stapp 1993/2003, p.157-9) According to that idea, the individual thought is *experienced* as a duration that is separated into a sequence of temporally displaced components corresponding to parts that have entered the stream at slightly displaced times. Thus it is *process in time* that is experienced, even though the manifestation in space-time is essentially instantaneous.

Whether the details of this rather general speculative framework can be specified in a way that will make it useful in science depends upon what new---for example, cosmological---kinds of empirical evidence need to be accommodated.

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